EVALUATION OF CANAL ORIFICE INTER-RELATIONSHIP AND CO-RELATION TO OCCLUSAL MORPHOLOGY IN HUMAN PERMANENT MANDIBULAR FIRST MOLAR TEETH: A IN-VITRO STUDY

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CERTIFICATE

This is to certify that **DR.NAGENDRAN. S,** *Post Graduate Student (2012-2015) from the Department Of Conservative Dentistry and Endodontics, J.K.K.Nataraja Dental College, Komarapalayam, Namakkal District–638183, Tamilnadu has done the dissertation titled* **"EVALUATION OF CANAL ORIFICE INTER-RELATIONSHIP AND CO-RELATION TO OCCLUSAL MORPHOLOGY IN HUMAN PERMANENT MANDIBULAR FIRST MOLAR TEETH: A IN-VITRO STUDY"** *under my direct guidance and supervision in the partial fulfillment of the regulations laid down by* THE TAMIL NADU DR. M.G.R MEDICAL UNIVERSITY, CHENNAI, FOR M.D.S BRANCH – IV CONSERVATIVE DENTISTRY AND ENDODONTICS DEGREE EXAMINATION. *It has not been submitted (partial or full) for the award of any other degree or diploma.*

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CONTENTS

INTRODUCTION

Successful treatment outcomes of endodontic therapy is consistently achievable by adequate awareness of anatomy of the root canal and its relationship to the morphology of the root and surrounding structures. The complexities of the root canal system have been analysed by various researchers as the clinician needs a clear and precise perspective of the presenting canal anatomy.

John Ingle in 1976[38] observed that 58.66% of failures of endodontic therapy could be as a result of incomplete canal obturation, and 9.68% to root perforations. Failure to recognize these variations and ramifications of root canal space can lead to incomplete and unsuccessful obturation. Though the principal root canal is considered the pathway of inserting endodontic instruments from the orifice to the apical foramen, the operator must be aware and always lookout for variations from normal.

The location of all the canals in a root canal system is very important as the presence of untreated missed canals could contribute to failures of therapy. Understanding the shape, curvature, the pulpal floor anatomy, the number of canals, their inter-relationship, and the incidence of variations contribute successful endodontic therapy. Co-relating this data with the occlusal surface is very important as it helps the correct localization of the orifices and chamber during the access cavity preparation (**Vertucci F.J.**[80] **in 2005**).

Pre-operative knowledge of the location of the orifices in relation to the occlusal surface, racial predispositions, variations with regard to sex, race and age would certainly contribute to the success of the endodontic treatment procedure. The objective of a three dimensional obturation of the root canal system with a hermetic seal after effective disinfection can be realized only when the intricacies of the root canal system are fully understood by the clinician prior to performing the procedure. Not only does he need to appreciate the root canal system as a network of canals with inter-communications and ramifications which reach the periodontium but also proper access to these canals without compromising the structural integrity of the tooth. Excessive removal of tooth structure to gain access and visibility would result in undue weakening and leading to later complications.

A properly designed access can only be done and achieved only if pre-operative planning is done on a case by case basis and also relational information of the pulp chamber and orifices to the occlusal surface is available and quantified. This process of bio-mechanical preparation of the coronal and radicular pulp complex is effectively achieved via four stages - pre-access analysis, de-roofing the pulp chamber, mapping the pulp chamber floor and root canal orifices, and subsequent instrumentation of the root canal system. The ideal access cavity is ideally prepared with a minimally invasive design which allows access and visualization of the orifices and the root canal system. Numerous techniques and strategies have been used to achieve the same. This minimally invasive approach also helps to conserve the strength of the remaining coronal tooth structure.

The mandibular first permanent molar is one of the earliest teeth to erupt and hence relatively more prone to caries, and is one which is most frequently treated endodontically. Normally the two roots of the mandibular first permanent molar presents with three root canals i.e. two in the mesial root and one in the distal root. Variations are possible from the normal by branching and inter-communications.

Access cavity preparation is a first step to successful endodontic therapy as it permits localization, bio-mechanical preparation, and disinfection. This step should be considered extremely important as the final outcome of therapy depends entirely on precise, proper execution of the access cavity preparation. An improper access cavity preparation could lead to complications i.e., missed canals, ledging, perforation, instrument separation and apical transportation. Suitable modification of the conventional access preparation has been suggested by some authors to achieve a straight line access to the apical third of the root canal system and such a procedure has been also shown to increase chance of identification of extra canals. Missed canals have been reported with a incidence of as high as 42% in teeth which required endodontic re-treatment by **Hoen and Pink in 2002**[34].

Investigators have suggested various techniques in identification of orifices and extra canals. Multiple pre-operative radiographs with different angulations and analysis, exploration of the pulp chamber with a sharp explorer, champagne bubble test using sodium hypochlorite, staining techniques, troughing of the grooves with ultrasonic tips, visualizing the bleeding points in the pulp chamber floor, use of specially designed irrigators to clean and dry the pulp chamber to aid visualization, dentin mapping, use of tomography, and use of magnification are techniques which have been suggested to locate the canal orifices successfully.

Vertucci F.J.in 2005[80] observes though various diagnostic methodologies and techniques have been advocated, and that the clinician can further improvise the design of the access cavity by co-relating the occlusal anatomy of the concerned tooth with the location of the root canal orifices. **Iqbal and Fillmore**[40] suggest that preoperative assessment and prediction of the detection of root canal orifices are of great value because they are the only information available before the initiation of endodontic therapy. Pre-access planning and pre-operative prediction should be done as a part of the root canal procedure which in turn would go a long way in providing a precise route map to the canal orifices without affecting the structural integrity of the tooth.

Plotino. G. et al[59] observes that tomographic techniques are a non-invasive and can be used for the three dimensional assessment of the root canal system before, during and after endodontic instrumentation. Recent advances in techniques of tomography gives lesser radiation exposure and higher image resolution. Advances in tomography technologies have seen the introduction of high resolution micro-CT, Cone-beam CT with new image analysis and image reconstruction techniques which provide information three dimensionally to the clinician for routine pre-operative endodontic and surgical treatment planning as well as post-operative assessment.

It has been routine practice to make an access in an appropriate position on the clinical crown and look for root orifices. Locating the root orifices in teeth that have cariously broken down, been heavily restored, gouged by previous access preparation or tilted or rotated teeth is difficult as the normal anatomy is compromised. **Krasner P. and Rankow H.J. in 2004**[46] in their assessment of the anatomy of the pulp chamber, have proved the existence of specific consistent landmarks which are quantifiable which makes the orifice location more systematic and rational.

The human mandibular first permanent molar predominantly has a two rooted morphological pattern and has been researched extensively. Variations in the number of canals in the permanent mandibular first molar tooth has been reported by various researchers and clinicians. Single canals, C- shaped canals, more than four canals too have been reported. A three rooted variation of the mandibular first molar has also been reported with a very high incidence in the mongoloid populations and to a lesser extent in the Caucasoid populations. Developmental anomalies and fusion of roots of the permanent mandibular first molar have also been reported.

During endodontic therapy when treating a mandibular first permanent molar the clinician should look for extra canals unless proved otherwise. Less common variations like two distal canals, middle mesial canal, a single root canal system, multiple canals, third disto-lingual root (radix entomolaris) and radix paramolaris have been reported by various researchers. C-shaped canal systems have also been reported though the incidence of which is relatively rare in the mandibular first molar. **Saini et al**[67] in a review of taurodontism emphasise that this anatomical variation that could occur in a normal population as well as certain other systemic conditions and requires special management as identification and localization of the orifices becomes difficult.

Operator experience also has an positive effect on the location and negotiation of difficult or additional canals (**Corcoran et al in 2007**[15]). After routine access preparation meticulous observation and exploration of the pulpal floor contributes to identifying aberrant orifices or systems. Rather than routinely performing the access preparation in a specific location and searching for the orifices, importance should be given to pre-operative planning of the access cavity based on the information available to us for the tooth on which the root canal therapy has been advised. The approach of a planned access cavity preparation would save a lot of time, place all the root canals and orifices and prevent unnecessary cutting of the tooth structure contributing to the overall rate of success of endodontic therapy.

This study aims to evaluate the interrelationship of orifices and correlate the landmarks on the occlusal surface in the human permanent mandibular first molar teeth.

REVIEW OF LITERATURE

The invitro studies of **Hess W. in 1925**[33], using canite casts demonstrated that the root canal anatomy of highly variable and complex. Many accessory canals are web-like communications in between them were noted in multi-rooted teeth. Of the 512 teeth he analysed he find 0.3% with one canal, 17.7% with two canals with three canals, and 4.1% with four canals. Hess's student, Zurcher in 1925, using Hess's technique, in his study of first permanent molars, obtained similar results.

The morphology of the mandibular first molar has, been described by **Lloyd Du Brul. E and Sicher** [70,71] as strongly compressed in a mesiodistal direction and show a distal curvature, and that the distal root is narrower bucco-lingually and wider mesio-distally than the mesial root and is fairly Straight. He also mentioned of the longitudinal groves. Which are deeper in the mesial root then the distal root. He described the distal root as having a single wide Canal and the mesial root as having two narrow canals Which develop from the longitudinal portion of a single slit like canal, which starts about the fourteenth year of life. The roots arise from a common stock and are arranged mesiodistally.

Abnormalities of the pulp chamber have also been described by Sicher and the accessory root canals have been mentioned as the most frequent anomalies. He divided accessory canals into three types.

TYPE 1: These canals are transverse canals and their development has been attributed to the presence of transverse blood vessels or nerves. They arise by fusion of the protruding walls in slit shaped canals as in the case of the mandibular first permanent molar.

TYPE 2: These canals are present only in the apical end of the root and are bound and divided from each other by cementum only. Their development is attributed to the irregularities of apposition of cementum at the root tip.

TYPE 3: These are lateral 'canals or pulpo-periodontal fistulas and are characterized by the fact that they penetrate the dentin and the cementum of the root. He also points out the difficulty the type two and three canals cause during endodontic therapy.

The root canal morphology of human permanent mandibular first molars were evaluated by plastic casts of the root canals by **Skidmore A.E. and Bjorndal A.M. in 1971**[73]. They found an increased incidence of a second distal canal and the presence of transverse anastamoses between the canals.

The percentage of mandibular molars with four canals as reported by **Pineda L. and Kuttler Y. in 1972**[57] is 34.1% and they used radiographs of extracted teeth for evaluation in this study.

Barker et al in 1974[4] injected red epoxy resin into the root canals to make transluscent replicas which were analysed. They showed three parallel root canals in the mesial root of the lower first permanent molar.

Vertucci F.J, and Williams R.G,. in 1974[78] on their study on root canal anatomy of mandibular first permanent molars have reported the maximum incidence of Type 4 canals in mesial roots and Type 1 canals in distal roots.

The root canal anatomy of mandibular permanent first molars have been analysed by **Vertucci FJ. in 1974**[78]. He reported the incidence of lateral canals in the mesial root as 45% and in the distal root as 30%, out of which the maximum amount of lateral canals were seen branching in the apical region.

The presence of three root canals in the mesial root has been shown in vivo by **Van Voorde H.E. et al in 1975[77].** They found that 31% of 136 mandibular molars-studied had four root canals.

Zeigler P.E. and Serene T.P. in 1976[89] stated that, if the first file placed in the distal canal of the lower first molar points to the buccal or lingual side, a second canal should be suspected and also that of two canals are present, each will be smaller than a single canal.

John Ingle in 1976[38] described that 58.66% of failures of root canal therapy could be attributed to uncompleted obturation of the canal space and 9.6% were attributed to root perforations. Thereby he stresses the importance of knowledge of root canal morphology, for successful outcome of endodontic therapy.

Slowely R.R. in 1979[74] describes the mandibular first permanent molar as having two roots, the mesial root containing two root canals and the distal root containing one large canal. The mesio lingual canal is larger and less curved than the mesio buccal, which has at a buccal curvature. The distal canal is broad bucco lingually and can present a great deal of variation. It may contain a dental bridge or a septum which divided into two canal, which may rejoin.

Hartwell G an Bellizzi R in 1982[90] on and invivo study of endodontically treated mandibular molars, found 35.1% of the samples as having four canals.

Weine F.S. in, 1982[83] states that recurrent exacerbations are usually treated via surgical procedures. If the reason for the exacerbation is an irritant in tine root canal, then surgical treatment could not be necessary. Thus he emphasized the need to cognizant of the multitude of anatomic variations existing in pulp space morphology. The mandibular first permanent molar has been described as having two separate and distinct roots, the mesial root having two canals and distal root with one canal. He also mentions at the pulp chamber- of the mandibular first permanent molar is most frequently exposed and needs endodontic treatment. He describes four common canal figurations.

A single canal from pulp chamber to apex.

Two canals leave the pulp chamber, merge to exit as one.

Two canals leave the chamber and exit the root in separate apical foramina.

One canal leaves the pulp chamber, deviates short of the apex into two canals and exits. He also mentions if the occurrence of two distal roots, particularly in oriental patients.

Variations in the number of root canals present in the mesial and distal roots of mandibular first permanent molars were studied in vivo by **Martinez-Berna And Badanelli P. in 1983**[49]. They found four molars with three root canals in the mesial root and one in the distal root. They also reported eight cases of three root canals in the distal root, a rare variation in their study of 2632 teeth.

Fabra-Campos H. in 1983[22] found that, out of the 219 mandibular first permanent molars he treated, six cases presented with three canals in the mesial root and three cases were with three root canals in the distal root.

A case of mandibular first permanent molar with three distal canals was reported by **Stroner F.W. et al., in 1984**[76], in a young black girl, where two distal roots were visualized in the radiograph. The distobuccal root had two orifices, two canals and two foramina. The distoloingual root had one orifice, one canal and one foramen. The author observes that clinicians should not become excessively alarmed by the increasing reports of bizarre pulpal anatomy and that the knowledge of their existence may occasionally enable them to treat a case successfully that otherwise might have ended in failure.

Richard G. Beatty and Carlos M. Interian in 1985[65] reported a case of mandibular first molar with five canals. Radiographs revealed two distal roots with three canals. Two of them were placed bucally while the third has placed distolingually. They emphasized the need to perform a complete examination of the pulpal floor of the tooth even after the anticipated number of canal orifices have been identified.

Fabra campos H in 1985[23] discusses the unusual root canal anatomy of mandibular first permanent molars n their study of 145 lower molar teeth. Four first permanent molars were found with five canals, mesial roots has three canals that terminated in two or three identical foramina. There were two distal canals in all four cases.

A case of five root canals in a mandibular first molar was described by **Shimon Friedman et al in 1986**[25]. Of the five canals three were located in distal roots. The distance of three roots was radiographically confirmed. Of the distal canals were buccally placed and one is lingually placed in buccolingual line. The mesial root had two canals.

Barnett F. in 1986[6] reported a case of a mandibular first permanent molar with a C shaped or a ribbon like canal. The mesiolingual orifice was not in lingual position. The second orifice was C shaped and is located on the buccal aspect of the floor of the chamber. It extended from the usual location of the mesiobuccal orifice to the location of the distal canal. The C shaped canal resulted from the continuity of the mesiobuccal and the distal canals via a through. They were continuous from the chamber floor to within 2 mm of the apex

Beatty et al in 1987[9] reported a case of a mandibular first and second molar found to contain five root canals. Recent literature pertaining to unusual root canal morphology has been reviewed. The authors strongly recommend for a complete and thorough examination of the pulp chamber floor for even seemingly straightforward and simple nonsurgical endodontic cases as this would provide a wealth of information.

Walker R.T. in 1988[81] describes the root form and the canal anatomy of mandibular first permanent molars in a southern Chinese population. 15% of the mandibular first permanent molars he examined had three roots. 96% of the teeth had 2 mesial canals and 45% had two distal canals. 28% of the teeth with two distal canals had two separate apical foramina.

Grossman L.I. et al in 1988[29] state that a straight root canal extending from the pulp chamber to the apex is uncommon and either a constriction before the apex, or a curvature is always present. It may be a gradual or a sharp curvature near the apex or gradual curvature with a straight apical ending. Double curvatures in the form of 'S' shape may also occur. The mesial root of the first mandibular molar almost always has two canals, which sometimes meet in a common foramen. Occasionally, the distal root contains two canals.

The inner surface of the root apex becomes lined with cementum and can even extend for a short distance of 1mm into the root canal, he also reports that the apical foramen is not always located in the centre of the root apex. There is also a high incidence of lateral canals and accessory foramina in the apical of the root. The root canals become narrower with increasing age, with the deposition of secondary dentin and reparative dentin. Apical foramina also deviate from the exact anatomical apex and their minor diameter becomes wider with increase in age. He also mentions of a third root in the mandibular first molar besides the two well differentiated mesial and distal roots, normally present. The third root was found to be placed either mesially or distally.

Fabra-Campos H. in 1989[24] in a clinical study of 760 mandibular first molars, showed that 20 (2.6 per cent) had three canals in the mesial root. Of these 20 teeth, 13 (65 per cent) had an intermediate canal which joined the mesiobuccal canal in the apical third. In six cases (30 per cent) it joined the mesiolingual canal in the same area. In only one case did the intermediate or third canal retain its individual nature and end in an independent foramen.

Wilcox L.R. et al., in 1989[85] studied the relationship of the access outline on the occlusal surface to the canal orifices in permanent mandibular first molars and reported that the access openings usually advocated are too far mesial and lingual and that this can result in severe undermining of the marginal ridge or perforation. This study was designed to relate, in molars, the access outline on the occlusal surface to the canal orifices. The occlusal surfaces of maxillary and mandibular molars were photographed and prints made. The crowns were then sectioned at the level of the pulpal floor to expose the canal orifices. Transparent photographs of the orifices were taken and projected on the occlusal photograph; the orifice locations were marked directly on the print. Orifice location demonstrated a fairly regular pattern relative to the occlusal surface in all four molar groups. The resulting outline scribed from the orifices tended to be centered mesiodistally on the crown of each group and did not extend to the marginal ridges. The results indicate that classic access drawings are too far mesial.

De Moor et al in 2004[18] reviewed the incidence of mandibular first molars with an additional distolingual root (radix entomolaris) and discussed clinical cases. They note that the incidence of these three-rooted mandibular first molars appears to be less than 3% in African populations, not to exceed 4.2% in Caucasians, to be less than 5% in Eurasian and Asian populations, and to be higher than 5% (even up to 40%) in populations with Mongolian traits. They discussed a total of 18 cases (12 root filled and six extracted mandibular first molars) in patients of Caucasian origin. They suggested a modification of the access cavity preparation extending towards the distolingual making it trapezoidal in shape. None of the orifices was located midway between the mesial and distal root component. They also observe three types of curvature of the disto-lingual root were detected: (I) straight or no curvature (two cases); (II) coronal third curved and straight continuation to the apex (five cases); and (III) curvature in the coronal third and buccal curvature from the middle third or apical third of the root (11 cases).The authors conclude that knowledge and awareness is a must of this unusual root morphology in mandibular first molars Caucasian people. They suggest that radiographs exposed at two different horizontal angles are needed to identify this additional root and that the access cavity must be modified in a distolingual direction making it into a trapezoidal shape.

The anatomy of the pulp chamber floor was evaluated by **Krasner. P and Rankow. H.J. in 2004[46].** They evolved specific relationships to the pulp chamber and crown and proposed the laws of centrality, concentricity and cemento-enamel junction.

Law of centrality: The floor of the pulp chamber is always located in the center of the tooth at the level of the cemento-enamel junction.

Law of concentricity: The walls of the pulp chamber are always concentric to the external surface of the tooth at the level of the cement-enamel junction.

Law of the cemento-enamel junction: The cemento-enamel Junction is the most consistent, repeatable land-mark for locating the position of the pulp chamber.

They also proposed the laws of symmetry 1 and 2, law of color change and laws of orifice location 1, 2, and 3.

Law of symmetry 1: Except for maxillary molars, the orifices of the canals are equidistant from a line drawn in a mesial distal direction through the pulp-chamber floor.

Law of symmetry 2: Except for the maxillary molars, the orifices of the canals lie on a line perpendicular to a line drawn in a mesial-distal direction across the center of the floor of the pulp chamber.

Law of Color Change: The color of the pulp-chamber floor is always darker than the walls.

Law of orifice location 1: The orifices of the root canals are always located at the junction of the walls and the floor.

Law of orifice location 2: The orifices of the root canals are located at the angles in the floor-wall junction.

Law of orifice location 3: The orifices of the root canals are located at the terminus of the root developmental fusion lines.

This proposal of a systematic anatomic approach to pulp chamber and orifice location with the aim of a rational endodontic therapy is achievable.

Vertucci F.J in 2005[80] in analysis of root canal morphology and its relationship to endodontic procedures laid emphasis on proper pre-operative assessment using radiographs together with a thorough clinical exploration of the interior and exterior of the tooth involved. He recommends magnification, illumination and multiple pre operative radiographs. A through understanding of the complexity of the root canal system is essential for the understanding the principles and problems of shaping and cleaning, for determining the apical limits and dimensions of the canal preparation and performing successful non-surgical procedures. He observed that the maxillary first molar had a very complicated canal shape at the apical third and this makes cleaning shaping and obturation difficult. This is especially so in the mesio buccal and disto buccal canals

Three dimensional imaging using micro-computed tomography for studying tooth macromorphology was evaluated by **Plotino et al in 2006**[59] and they concluded that micro-CT offers a reproducible technique for 3D non-invasive assessment of root canal systems. They observed that while this system is not suitable for clinical use it can be applied to improve the preclinical training and analysis of fundamental procedures in endodontic and restorative treatment. Significant improvements in both software and hardware reduced the section thickness from conventional CT ranges of 1.5mm to those in the micro-CT systems to 81 micrometers, 34 micrometers and 12.5 micrometers. This has also proved to be a valuable technique for three dimensional non-destructive technique for reconstruction of the tooth structure. The advantage of using this technique is that it can show the internal and external anatomy simultaneously or separately.

Raturi et al in 2006[60] on their study of the pulp chamber observe that the anatomy of the pulp chamber has been perplexing even for the endodontist. In this in vitro study the teeth were analyzed for the various laws put forward by Rankow and Krasner. They confirmed the validity of these laws.

Calberson F L et al in 2006[12] observe that mandibular first molars can have an additional root located lingually (the radix entomolaris) or buccally (the radix paramolaris) and an awareness and understanding of this unusual root and its root canal morphology can contribute to the successful outcome of root canal treatment. They discuss management of three mandibular molars with a radix entomolaris or paramolaris, both of which are rare macrostructures in the Caucasian population. The prevalence, the external morphological variations and internal anatomy of the radix entomolaris and paramolaris are discussed by the authors.

Chogle et al in 2007[14] in their study recognize the need for conserving the tooth structure and have evaluated the cusps of the mandibular first molar in relation to the orifices in a invitro setting. They advocate a systematic approach to pulp chamber access procedure. By correlating the occlusal anatomy with the location of the root canal orifice, they observe that a number of guidelines for improving access design could be formulated. The radiographs taken at different stages were superimposed and evaluated for occlusal and pulpal patterns. They conclude that the canal orifices at the pulp chamber floor level exhibited a consistent pattern relative to the cusp tips.

Cotton et al in 2007[16] evaluated the endodontic applications of volumetric cone beam tomography. They reviewed the cone beam computerized tomography system and charted out the advantages of the system over medical-CT and conventional radiography. They observed specific endodontic applications of cone beam volumetric tomography which include diagnosis of endodontic pathosis and canal morphology, assessment of pathosis of non endodontic origin, evaluation of root fractures and trauma, analysis of external and internal resorption of the root, invasive cervical resorption and presurgical planning. It has got a great potential to become a popular treatment planning tool in endodontic practice. It has more accuracy, resolution, reduced scan time and reduction in radiation dose when compared to a medical-CT. As compared to conventional radiography it eliminates superimpositions of surrounding structures, distortion and provides additionally relevant clinical information. The drawbacks include limited availability, significant capital investment and medico-legal considerations.

Corcoran et al in 2007[15] determined the influence of operator experience on the ability to locate and fill extra canals in maxillary first molars in-vivo, and found that it definitely improved the rate of identification of new canals. With experience the operator schedules more time to search for additional canals. The operating microscope may have also contributed to increased confidence and boldness in searching for second mesiobuccal canals. Collectively this additional experience increases the number of additional canals found in maxillary first molars. Trained endodontist become more proficient in finding extra canals with experience.

Mickel A K et al in 2007[50] in their invitro study observe that pulp chamber and root canal orifices should be located by a technique that is consistent and accurate. The investigators sought to determine if correlation exists between occlusal surface morphology, pulp chamber location, and root canal orifices. For each specimen, amalgam restorations were placed in cusp tips, and gutta-percha placed in each canal at the level of the furcation. The authors co-related digital radiographs and occlusal photographs by super-imposition technique with a digital software program before and after sectioning of the teeth at the cemento-enamel junction level. The authors concluded that the pulp chamber of the mandibular first molar lies more lingual at the cemento-enamel junction level and that the orifices were consistent in their location relative to cusp tip anatomy.

Iqbal and Fillmore in 2008[40] preoperative predictors of number of root canals clinical detected in maxillary molars they found that when other variables were controlled only the age of the individual was significantly related to the number of canals detected. They observe that the most important factor in locating the second mesiobuccal canal is not the magnification but operator persistence.

On a review of advanced digital imaging in endodontics **Patel et al in 2009**[55,56] observe the role of cone beam computerized tomography and micro-CT and medical-CT as relevant to the practice of endodontics. They observe that the age of three dimensional imaging is here and have provided the endodontist with tools that were not available to the clinician before and facilitated interactive image manipulation and enhancement to visualize the area of interest as a 3D volume Lack of distortion, magnification, artifacts associated with conventional radiography and the relative low radiation dose in comparison with a medical grade CT will result in more clinicians adopting such a technology to enable accurate diagnoses and treatment planning.

Georghita et al in 2009[27] describe the access cavity as the first step in a successful endodontic preparation and observe that a improperly prepared access in terms of position depth or extent will hamper the achievement of proper results and ultimately lead to failure by perforation, ledge formation, instrument separation, zipping or apical transportation. They observe that the basic principles of outline, convenience, removal of carious dentin and toilet of the access cavity should be done. Complete control of the enlarging instruments is necessary for the clinician and this is possible only when a proper access has been achieved.

De Pablo et al in 2010[19] in a systematic review of the root canal anatomy and configuration of the permanent mandibular first molar observe that Forty-one studies were done on 18,781 teeth. The incidence of a third root was 13% .Three canals were present in 61.3%, 4 canals in 35.7%, and 5 canals in approximately 1%. Root canal configuration of the mesial root revealed 2 canals in 94.4% and 3 canals in 2.3%. The most common canal system configuration was Vertucci type IV (52.3%), followed by type II (35%). Root canal configuration of the distal root revealed type I configuration in 62.7%, followed by types II (14.5%) and IV (12.4%). The presence of isthmus communications averaged 54.8% on the mesial and 20.2% on the distal root. They concluded that the variations of root configuration and morphology might present the clinician situations which require more precise diagnostic approaches, access modifications, and clinical skills. This methodology would help the clinician to successfully localize, prepare and obturate the root canal space.

Wang et al in 2011[82] in a study of the root and canal morphology of mandibular first permanent molars in a western Chinese population by CBCT and concluded that there was a increased incidence of four canals in the first molar and a separate distolingual canal.

Chandra S S et al in 2011[13] analysed the prevalence of three rooted mandibular first molar in a south Indian population and found a rate of incidence of 13.3 %, and observe that though that is less than that of the incidence in the mongoloid populations, the operator should be prepared to handle such variations.

Attam K et al in 2012[1] has reported a case of radix entomolaris and have observed that to occur with a frequency of 0.2–32% in different populations. The observe that it is very crucial to ascertain the exact nature of this variation in terms of curvature and conformation to carry out a proper treatment protocols the ensure success of endodontic therapy. Proper interpretation of radiographs, using different horizontal cone projections and advanced tools such as CBCT, may facilitate their recognition. They suggest management of the extra canal and root can be done using equipments such as magnification aids, orifice locators and flexible files.

De Pablo et al in 2012[20] on the clinical implications and recommendations in the variations in the anatomy of the human mandibular first permanent molar note that root canal anatomy may presents a complex clinical challenge that requires special access modification diagnostic approaches, and methodologies. Additional clinical skills have to be acquired to successfully localize, negotiate, disinfect, prepare and obturate. Canal morphology is directly influenced by ethnicity and has a significant effect on treatment protocols. Mesial roots present two canals on a regular basis, adopting 2-2 and 2-1 as the most common configurations. A third canal is present in 2.6% of the population. The most common configuration in the distal root is type I (62.7%), followed by type II (14.5%) and type IV (12.4%). Diagnosis and treatment of complex root canal systems often require specialized training that may be beyond the scope of the average general practitioner. Access modifications are required to find extra roots and/or canals. The incidence of isthmuses is 55% in the mesial root and 20% in the distal root of the mandibular first molar. The instrumentation of the third root requires a different access and flexible instruments, given the curvature that is usually present in the apical third.

Abella F et al in 2013[2] reviewed the prevalence and morphologic classification of human mandibular first molars with disto-lingual roots, and discussed approaches and methodologies for successful therapy. Electronic and hand databases, which covered all publications from 1970 to December 2011. Two reviewers independently assessed the studies and recorded type of study, origin and sample sizes, number of teeth with three roots and type of root canal configuration. Forty-five studies were identified with a total of 19,056 mandibular first molar teeth. The incidence of the distolingual root was 14.4% and had specific associations with certain ethnic populations. The most common canal configuration of mesial and distal roots was Vertucci types IV and I, respectively. No significant differences were observed in prevalence of distolingual roots according to gender, had a greater angle of curvature and a smaller radius of curvature in a bucco-lingual orientation and was shorter than disto-buccal roots. Variable results related to side were observed as well as a trend in bilateral occurrence. They can be best identified using a a 25° mesial parallax periapical radiograph or cone-beam computed tomography. The authors recommend a modification of the access preparation from triangular to trapezoidal shape for easy location of the orifice. They also note that variable furcation levels during coronal pre-flaring or post-space preparation to avoid furcal/strip perforations should be done to avoid weakening of DL roots.

Bains R et al in 2013[7] reported a case of a three rooted mandibular first molar with a adjacent two rooted premolar and successfully managed the case. They conclude by suggesting that adequate knowledge, proper diagnosis, use of diagnostic aids and appropriate modification of the procedures to adapt to individual situations would lead to successful therapy.

Ballullaya S V et al in 2013[3] in their review article list out all the variations of permanent mandibular first molar published so for in the literature. Total ninety seven articles were selected out of which 50 were original article and forty seven were case reports. The incidence of three rooted mandibular first molar was 3% to 33% and only nine cases reported with c shaped canals. The incidence of third canal in mesial root was 0.95% to 15%. Only ninety cases reported with c-shape canal configuration. Taurodontism was more common in cases with congenital disorders. They observe that with use of proper diagnosis, appropriate modification in access, use of magnification, disinfection and obturation techniques are vital for success of therapy.

Bonaccorso A et al in 2013[11] reported a case of variant morphology of the pulpal floor and demonstrates anatomical variations in mandibular first molars. The mandibular first molar had three separate roots and the pulp chamber floor revealed four separate canal orifices. The authors observe that there are very few cases of a first mandibular molar with three separate and divergent roots, which is a rare anatomical configuration. They suggest modification in shape of access cavity to locate an extra root canals in the floor of the pulp chamber. A trapezoidal shape in mandibular first molar would greatly aid the easy location of the second distal canal.

A similar modification of the access cavity by extension slightly towards disto-lingual to locate the extra disto-lingual root orifice would result in a square shaped rather than a triangular access preparation.

Jang J K et al in 2013[41] in their study evaluated the prevalence of three-rooted permanent mandibular first molars with four canals and their morphological characteristics among a Korean population using cone-beam computed tomography. The incidences of three-rooted mandibular first molar was compared with regard to gender and location. Inter-orifice distances between distobuccal and distolingual canals were measured at pulpal floor and furcation levels. The difference between males and females for the values of inter orifice distance was also analyzed using chi-square tests. Of the 225 females and 247 males investigated, 84 females and 107 males were found to have at least one three-rooted mandibular first molar.. Among the 780 permanent mandibular first molars analysed, 191 (24.5%, 89 of 397 left and 102 of 383 right) were found to have three roots. The mean inter-orifice distance between distobuccal and distolingual canals at the pulpal floor level was 3.1 mm in males and 2.9 mm in females. The authors concluded that the occurrence of three-rooted among a Korean population was 24.5% and was higher than other countries and ethnicities. The authors conclude that knowledge of incidence of three-rooted permanent mandibular first molars with four canals and the distance between two distal canals may increase the success rate of root canal treatment by reducing failure rates.

Souza-Flamini et al in 2014[75] evaluated the supernumerary third root or the radix in mandibular first molars using micro-computed tomography (μCT) scanning.

They examined nineteen teeth for root length, root curvature direction, location of radix, apical foramen, accessory canals and apical deltas, and distance between canal orifices as well as 2- and 3-dimensional parameters of the canals (number, area, roundness, major/minor diameter, volume, surface area, and structure model index). The analysis of quantitative data was done by 1-way analysis of variance and the Tukey test The authors found that the mean length of the mesial, distal, and radix roots was 20.36 ± 1.73 mm, 20.0 ± 1.83 mm, and 18.09 ± 1.68 mm, respectively. The radix was located distolingually in 16 teeth, mesiolingually in one and distobuccally in one tooth. In a proximal view, most radix roots had a severe curvature with buccal orientation and a buccally displaced apical foramen. They also observed that the configuration of the canal orifices on the pulp chamber floor was mostly in a trapezoidal shape. The radix root canal orifice was usually covered by a dentinal projection. The radix differed significantly from the mesial and distal roots for all evaluated 3-dimensional parameters and had a more circular shape in the apical third, and the mean size of the minor diameter 1 mm short of the foramen was 0.25 ± 0.10 mm. The authors conclude that this is a important and challenging anatomic variation of mandibular first molars, which usually has a severe curvature with a predominantly distolingual location, and presents with a narrow root canal with a not so easy access.

MATERIALS AND METHODS

ARMAMENTARIUM

COLLECTION OF TEETH

1. Normal Saline solution (Nirlife Health Care, Nirma Products, India)
2. Vented glass bottles
3. 3% hydrogen peroxide solution (Nice chemicals pvt ltd, India)
4. 2.5% Sodium hypochlorite solution (Nice chemicals pvt ltd, India)
5. 5% Sodium hypochlorite solution (Nice chemicals pvt ltd, India)
6. 0.1% Thymol solution (Alpha Chemicals, Maharastra, India)
7. 5% Sodium thiosulphate solution (Nice chemicals pvt ltd, India)
8. Sterile Distilled water (Ives drugs Pvt Ltd, India)
9. Ultrasonic scaler - (EMS - Electro Medical Systems)
10. RadioVisuoGraphy unit Kodak (Carestream pvt Ltd.)
11. X- Mind Ac/Dc Radiography unit, (Satelec Systems, Italy)

SELECTION OF SAMPLES

1. Magnifying loupe with illumination (Vococal, Guangdong China)
2. Tissue forceps (GDC marketing company, punjab, India)
3. Explorer D/E # 5 (GDC marketing company, punjab, India)
4. Explorer DG-16 (GDC marketing company, India)
5. Ultrasonic scaler- tip size PS (EMS - Electro Medical Systems)
6. Stainless steel trays (SAIL)
7. Labelled glass bottles

ARMAMENTARIUM

Fig 1 : Prepared samples

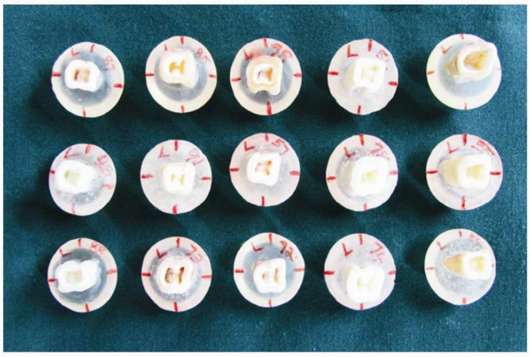


Fig 2 : Sectioned samples

Fig 3 : Imaging unit

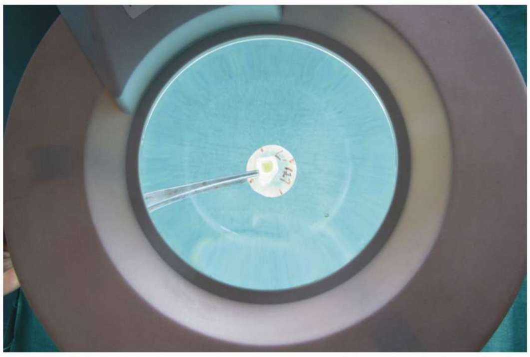


Fig 4 : Magnification loupe

Fig 5 : Operating microscope

Fig 6 : Diamond disc

SAMPLE PREPARATION

1. Auto polymerizing Resin (DPI Self cure Resin, mumbai, india)
2. Die Stone (kalabhai)
3. Custom base preparation block
4. Marker Pen Red & Green
5. Zip-lock covers with label (AK Product; West Bengal; India)
6. Storage boxes for group L & R
7. Dappen dish
8. Vaseline
9. Acrylic trimmer
10. Polishing motor
11. Pumice
12. 10ml syringe (Dispovan, Hindustan Syringes and Medical Devices Ltd, Faridabad, India)
13. Micromotor handpiece (NSK, Nakanishi Inc,japan)
14. Polishing brush
15. Stainless steel measuring scale

IMAGING PROCEDURE

1. Custom Sample orientation block
2. Custom jig setup for image capture
3. Nikon D800 SLR 14.1-megapixel FX-format CMOS sensor Camera (Nikon Inc. Melville, U.S.A)
4. Illumination unit

ARMAMENTARIUM

Fig 7 : Instrument kit

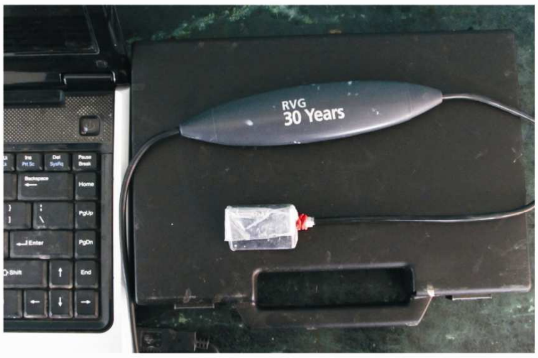


Fig 8 : Radiovisiography unit

Fig 9 : Radiography unit

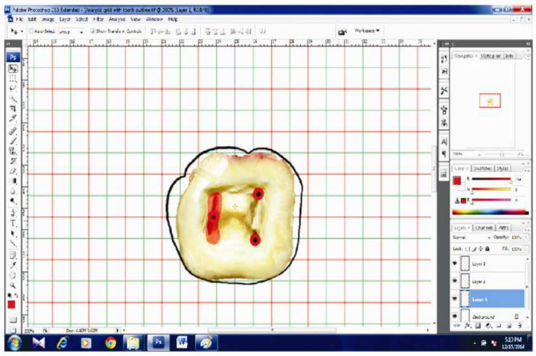


Fig 10 : Adobe image analysis

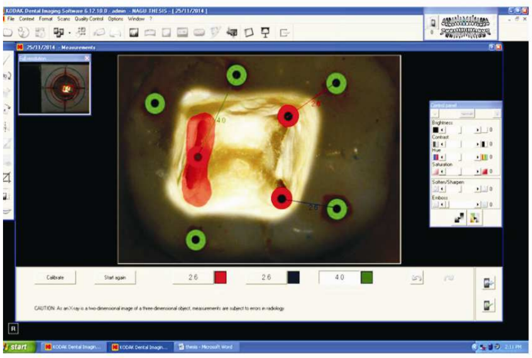


Fig 11 : Kodak software analysis

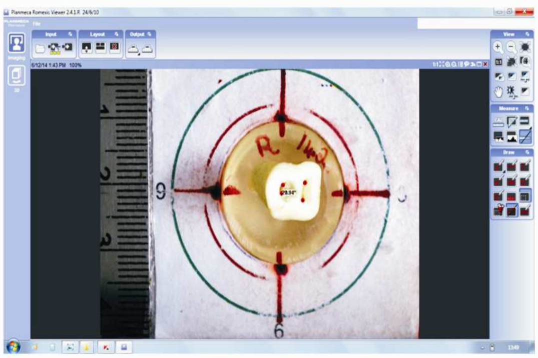


Fig 12 : Planmeca software analysis

SECTIONING OF SAMPLES & DEBRIDEMENT

1. High speed motor
2. Diamond disc
3. Ultrasonic scaler tip size PS (EMS - Electro Medical Systems)
4. 5% Sodium hypochlorite solution (Nice chemicals India ltd)
5. Endosonic tip RT1 (EMS - Electro Medical Systems)
6. Micromotor Handpiece (NSK Nakanishi Inc ,japan)

ORIFICE LOCATION

1. Medium and fine grid diamond tapering fissure bur 848 (SS White Burs, Inc. Lakewood, NJ USA)
2. Ultrasonic Scaler -EMS
3. START X Endosonic tip size 2 & 3 (Dentsply Maillefer, Ballaigues, Switzerland)
4. Size 6, 8, 10 size K files of 21mm (Dentsply, Maillefer, Ballaigues, Switzerland)
5. Surgical operating microscope model AM 3000 (Vaansari marketing company, India)
6. Explorer DG-16 (HU FRIEDY, Rockwell, Chicago)
7. 10 ml syringe (Dispovan, Hindustan Syringes and Medical Devices Ltd, Faridabad, India)

SOFTWARE ANALYSIS

1. Adobe Photoshop CS3 Extended, V. 10.0.1 (Adobe Inc., San Jose, CA, USA)
2. Planmeca Romex Viewer 2.4.I.R Image Analysis Software (Planmeca Oy, Helsinki, Finland)
3. Kodak Image analysis software 6.12.10.0 version (carestream inc 2007, Vaughan)
4. COREL DRAW X5 version (corel corporation, Ottawa, ON, Canada)

METHODS

1. COLLECTION AND PREPARATION OF SAMPLES

Four Hundred and two freshly extracted human permanent mandibular first molar teeth were collected after extraction and placed in an normal saline solution. They were then rinsed in running water and placed in a 3% hydrogen peroxide solution, rinsed again with distilled water and subsequently placed in a 2.5% sodium hypochlorite solution for 24 hrs. They were then rinsed with distilled water, and subsequently with .5% sodium thio-sulphate solution and stored in a .1% thymol solution, Protocols in cross-infection control as per OSHA /CDC guidelines in storing, surfacing & re-utilization were observed.

2. SELECTION OF SAMPLES

Subsequent to the collection and preparation process the samples were observed under a magnifying loupe for intact occlusal and root morphology. Teeth with large caries lesions, loss of morphological landmarks, cracked teeth, and broken roots were discarded. The selected teeth were then placed in a 3% sodium hypochlorite solution for 48 hours and the solution changed every six hours.

The surface of the teeth were cleared of external debris, calculus and soft tissue by using ultrasonics. The teeth were rinsed in running water and were then analyzed using digital radiographs. A total of three hundred and fourteen teeth were selected for the study and divided into two groups. Group L(Left mandibular first permanent molars) and group R(Right mandibular first permanent molars). Group L consisted of 155 Human Left mandibular first permanent molars (n=155) and group R consisted of 159 human right mandibular first permanent molars (n=159).

Both the groups rinsed with sodium thiosulphate solution and then stored in a 1% thymol solution at room temperature (30^0 celsius) in separate bottles and labelled.

3. PREPARATION OF THE SAMPLES

The roots of teeth belonging to both the groups were placed in a base former and auto polymerizing resin was poured to serve as a base for a height of 8 mm. They were then removed and the surfaces smoothened and polished. The samples were then coded and numbered separately with left and right markings so that they were visible during the image analysis procedure and stored in separate pouches for further analysis.

4. OCCLUSAL IMAGING PROCEDURE

A special custom block for placing the samples with bases before photography was constructed with markings for alignment during imaging and with a reference of a stainless steel millimeter scale of 0.5mm for grid pattern generation. The cuspal tips were also marked as points on the samples.

An imaging jig was constructed with fixed reference points, focal length and distance and which was further confirmed by the cameras optics alignment software. The imaging was done against a black background to avoid scattering of light. The block placement was also standardized for consistency during the occulsal imaging process and subsequent imaging of cut samples. The images were recorded using a

NIKON D700 SLR digital camera. Each image was coded and stored separately for each group

5. SECTIONING OF THE SAMPLES

The samples of both the groups were sectioned at the level of the cemento-enamel junction using a diamond saw with water coolant. Care was taken not to break the occlusal portion. After separation coding was done immediately on the occlusal portion and stored together.

6. DEBRIDEMENT AND PREPARATION OF THE PULP CHAMBER

Each of the cut sample was then taken and the pulp chamber debrided with a ultrasonic tip with coolant. Irrigation was done with 5% sodium hypochlorite solution at 45^0 c which was allowed to remain in the chamber for five minutes after which the pulp chambers of specimen was cleaned using an endosonic tip (EMS). It was then irrigated using a 5% sodium thiosulphate solution to neutralise the hypochlorite. A tapering but under low speed was used carefully only on the walls of the chamber without touching the pulpal floor so as to make the orifices clearly visible when viewed from top. The samples were dried.

7. SECTIONED SAMPLE IMAGING PROCEDURE

The section and prepared samples were then placed on the same custom sample placement block and the imaging procedure done using the customized jig setup with the same reference markers, used for the occlusal imaging process. The images were subsequently recorded for each sample, coded and stored.

8. ORIFICE LOCATION

All the samples were analyzed under a operating microscope under 12.8x magnification. The pulp chamber floor was searched for root canal orifice, presence of isthmus and pulpal floor morphology. The observations were recorded. Each of the orifice observed was negotiated using a 8 size K-file (Dentsply, Maillefer, Ballaigues, Switzerland) and confirmed with a RVG for location of the exit of the canal to a specific root, specifically for the additional variant orifices. Deviations from normal in each group were recorded with regard to the type of variation.

9. SOFTWARE ANALYSIS

ORIFICE VALIDATION

The images were then processed using a image analysis software (Adobe Photoshop CS3 Extended, V.10.0.1; Adobe Inc., SanJose, CA, USA) and the orifices shaded, the centre of the orifice were also marked. These images were stored separately in JPEG format. These stored images were co-related to the samples using an independent second operator with a operating microscope to verify the validity of recorded data and appropriate corrections and adjustments done.

ANGLE MEASUREMENT

The various angles between the orifices were also calculated using Planmeca Romexis Viewer 2.4.I.R, an image analysis software. The following set of angles were that of between the orifices mesiobuccal, mesiolingual, distal and distolingual were calculated and recorded **(fig:13-28)**

SINGLE DISTAL CANAL

ANGLE A = MB – ML MIDPOINT – DISTAL ORIFICE – MB ORIFICE

ANGLE B = MB – ML MIDPOINT – DISTAL ORIFICE – ML ORIFICE

ANGLE C = MB ORIFICE ---- DISTAL ORIFICE – ML ORIFICE

ANGLE D = ML ORIFICE ---- MB ORIFICE ------ D ORIFICE

ANGLE E = MB ORIFICE ---- ML ORIFICE ------ D ORIFICE

SECOND DISTAL CANAL

ANGLE F = D1------MIDPOINT OF MB-ML – D1-D2 MIDPOINT

ANGLE G = D2------MIDPOINT OF MB-ML – D1-D2 MIDPOINT

ANGLE H = MB-------------------ML --------------D1-D2 MIDPOINT

ANGLE I = ML-------------------MB --------------D1-D2 MIDPOINT

ANGLE HI = D1------MIDPOINT OF MB-ML – D2

DISTOLINGUAL CANAL

ANGLE J = MB -------------------D --------------DL ORIFICE

ANGLE k = DL------MIDPOINT OF MB-ML – D-DL MIDPOINT

ANGLE L = MB -------------------ML --------------DL ORIFICE

The results were tabulated and subsequently analysed.

MATERIALS AND METHODS

ANGLES - SINGLE DISTAL CANAL

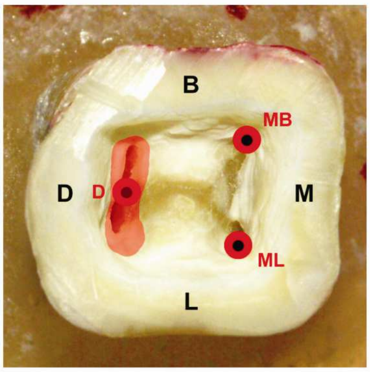


Fig 13 : Molar with single distal canal

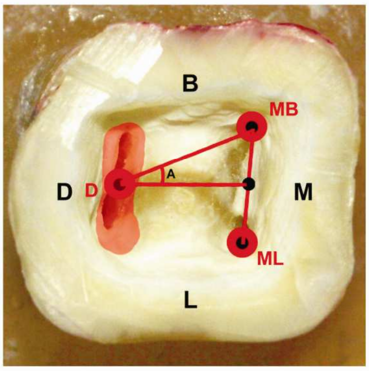


Fig 14 : Angle A

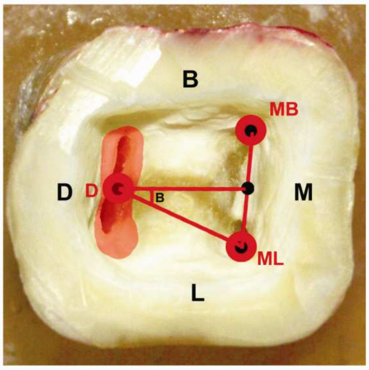


Fig 15 : Angle B

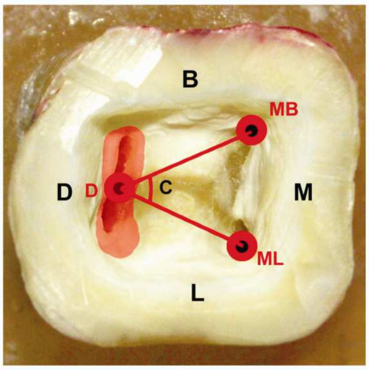


Fig 16 : Angle C

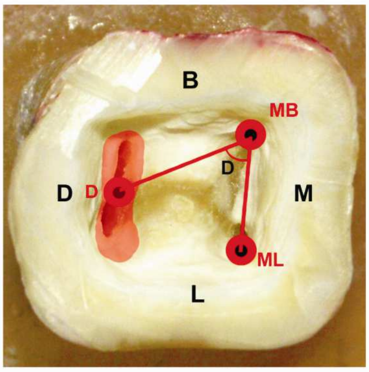


Fig 17 : Angle D

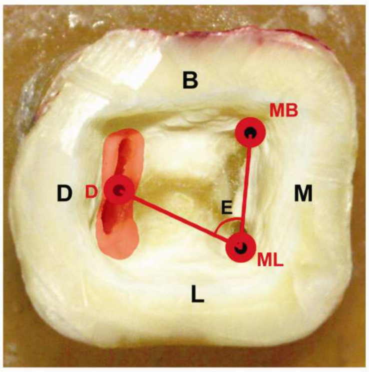


Fig 18 : Angle E

MATERIALS AND METHODS

ANGLES - TWO DISTAL CANALS

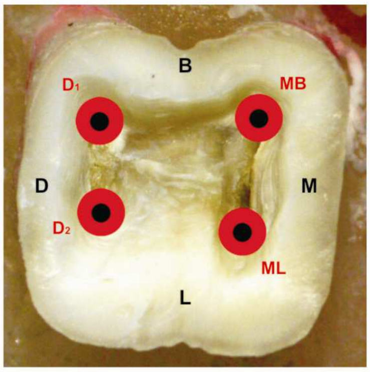


Fig 19 : Molar with two distal canals

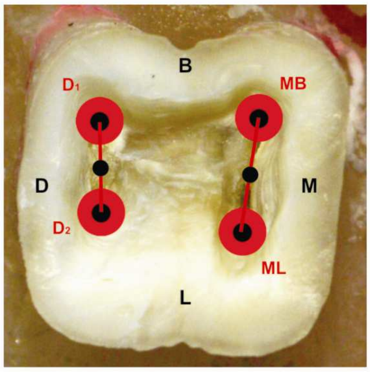


Fig 20 : Midline marked between two distal canals

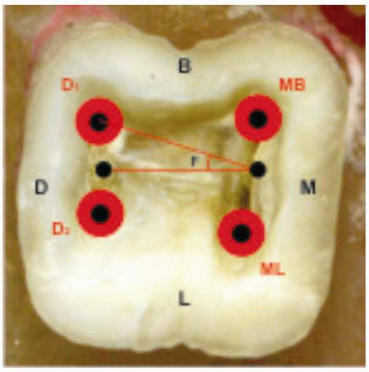


Fig 21 : Angle F

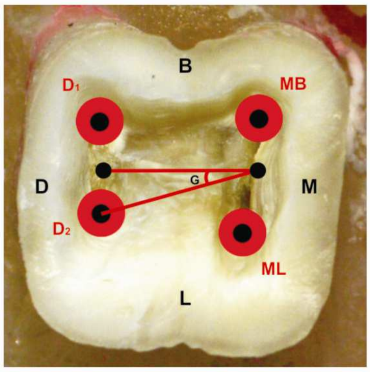


Fig 22 : Angle G

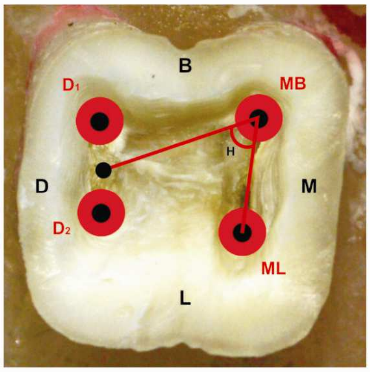


Fig 23 : Angle H

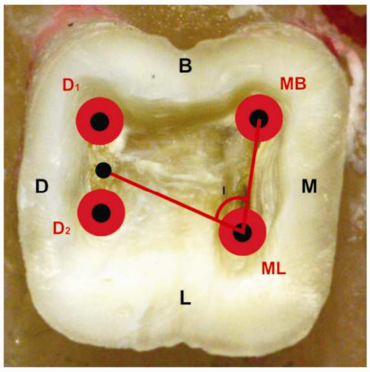


Fig 24 : Angle I

MATERIALS AND METHODS

ANGLES - DISTO LINGUAL CANAL

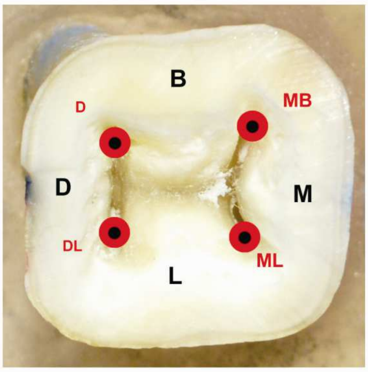


Fig 25 : Three rooted molar

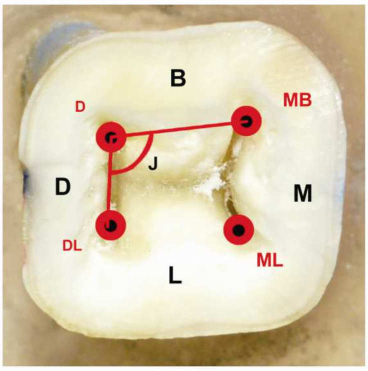


Fig 26 : Angle J

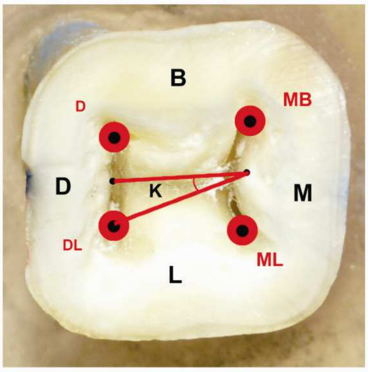


Fig 27 : Angle K

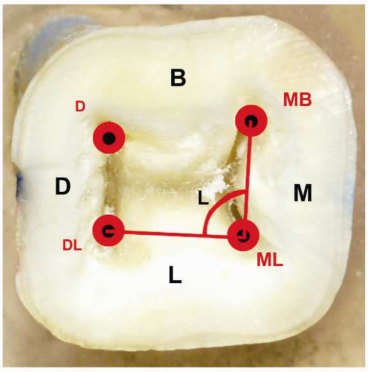


Fig 28 : Angle L

DISTANCE MEASUREMENT

The cusp tip to orifice distances, inter cuspal distances were calculated using an image analysis software (Kodak image analysis software 6.12.10.0) designed for that purpose, and the results recorded. The following **cusp tip to orifice distances** were recorded (fig 7).

Distance a : Mesio buccal cusp tip to Mesio buccal orifice

Distance b : Mesio lingual cusp tip to Mesio lingual orifice

Distance c : Disto buccal cusp tip to Distal orifice

Distance d : Disto lingual cusp tip to Distal orifice

Distance e : Disto buccal cusp tip to Midpoint of D1-D2

Distance f : Disto lingual cusp tip to Midpoint of D1-D2

Distance g : Distal cusp tip to Distal orifice or Midpoint of D1-D2

Distance h : Distal cusp tip to Midpoint of Distal-Distolingual orifice

Distance i : Disto lingual cusp tip to Disto lingual orifice

The following **inter-cuspal distances** were recorded (fig 7).

Distance j : Mesio buccal cusp tip to Mesio lingual cusp tip

Distance k : Disto buccal cusp tip to Disto lingual cusp tip

MATERIALS AND METHODS

DISTANCES

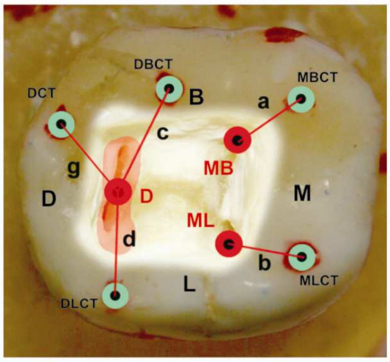


Fig 29 : Distance - Single distal canal (a,b,c,d,g)

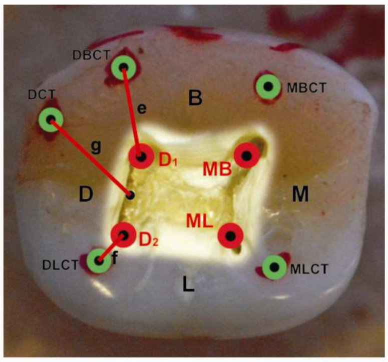


Fig 30 : Distance - 2 distal canals (e,f,g)

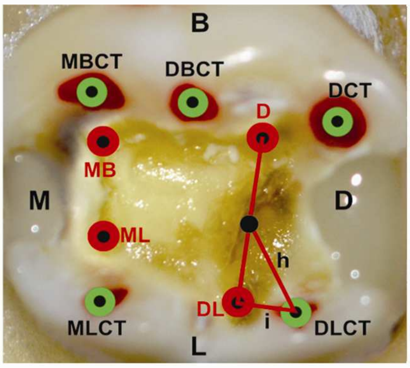


Fig 31 : Distance - distolingual canal (i,h)

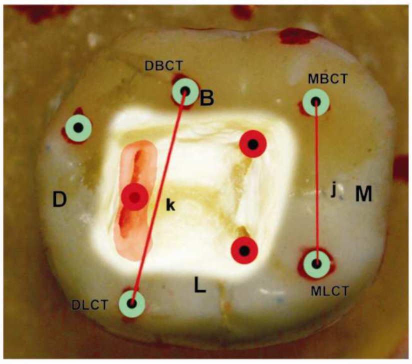


Fig 32 : Distance - intercuspal distance (j,k)

COMPOSITE IMAGE ANALYSIS

The final images of the pulp chamber floor with orifices were analysed after super-imposition with the occlusal image by a stacking process using a image processing software (Adobe Photoshop CS3 Extended, V. 10.0.1; Adobe Inc., San Jose, CA,USA) the exact alignment was achieved by alignment of reference marks on both images which was placed on the block prior to the image capturing process .The visualization of the orifices in the lower layer (post sectioning image) was achieved by removing the region overlying than in the upper layer (occlusal surface image). The resultant image was saved as JPEG format and coding done.

GRID ANALYSIS

A 0.5mm grid was developed with the x-axis serving as the mesio- distal and y-axis serving as the bucco-palatal bisectors of the tooth crowns. To enable plotting of the co-ordinate of each canal orifice. The 0.5mm grid plane was super-imposed digitally on the stack on the mesio-distal and bucco-palatal axis of the crowns by COREL DRAW X5 image analysis software. The co-ordinates of the canal orifices were recorded and the distribution of the orifices with respect to each tooth quadrant was done. Further a frequency distribution map was also generated.

The results were enlarged, printed and subsequently analysed.

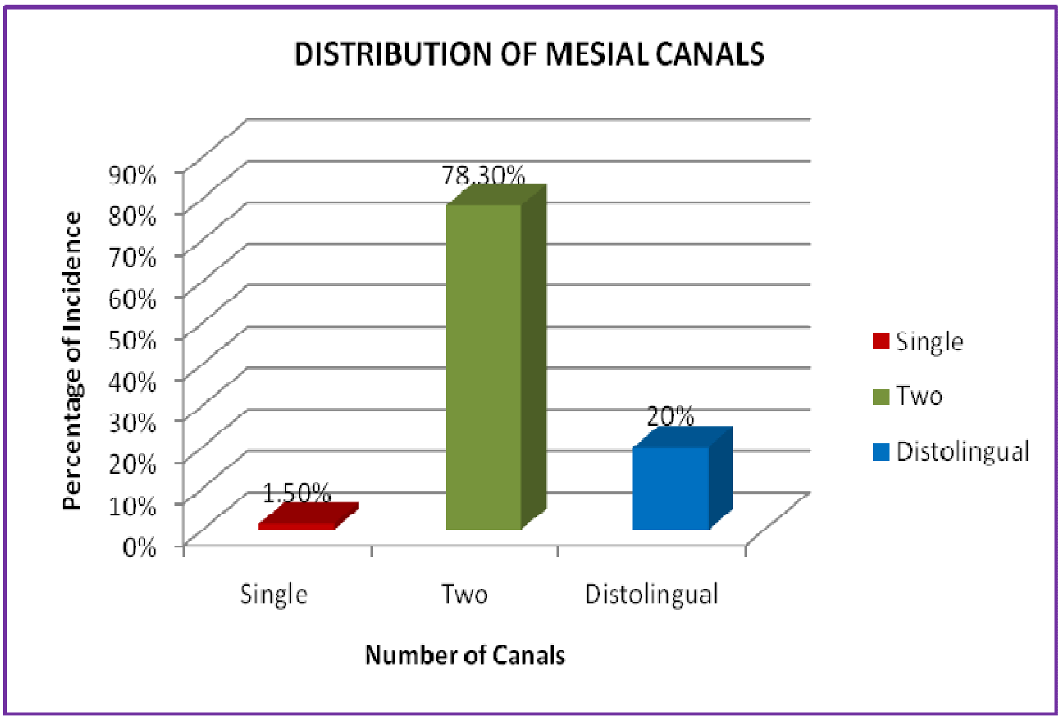
RESULTS

HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE I : DISTRIBUTION OF MESIAL CANALS

Total No. of samples (n=314)	Single Mesial	Two Mesial	Three Mesial
314	5	246	63
Percentage of incidence	1.50%	78.30%	20%

CHART I



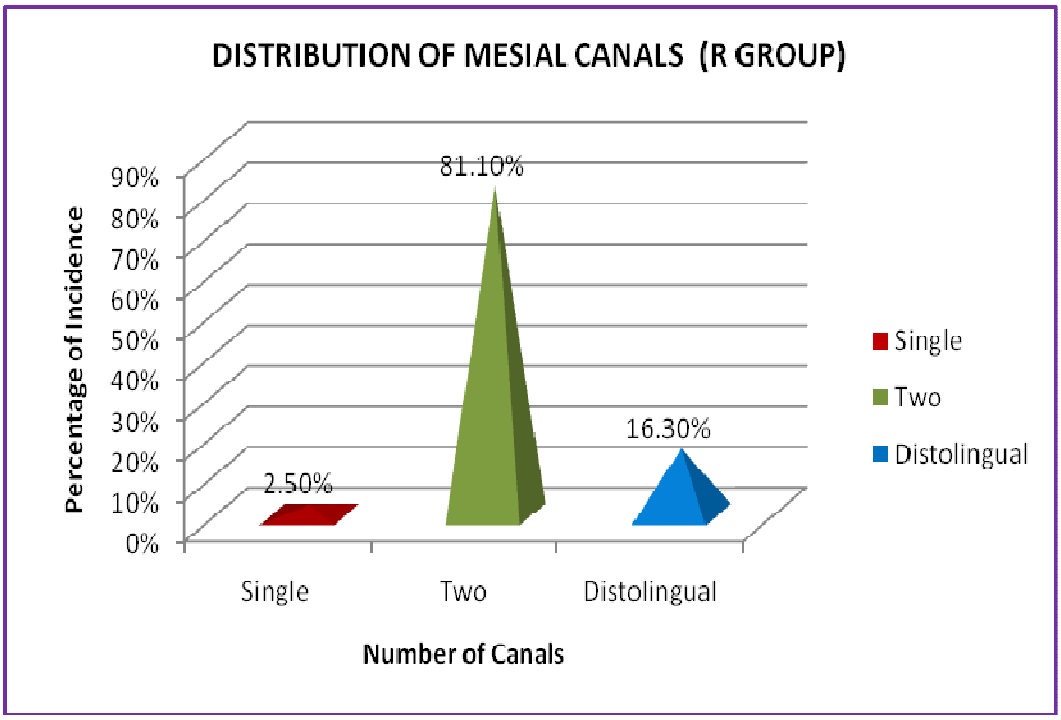
HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE II : DISTRIBUTION OF MESIAL CANALS

R GROUP

Total No. of samples (n=159)	**Single Mesial**	**Two Mesial**	**Three Mesial**
159	4	129	26
Percentage of incidence	2.50%	81.10%	16.30%

CHART II



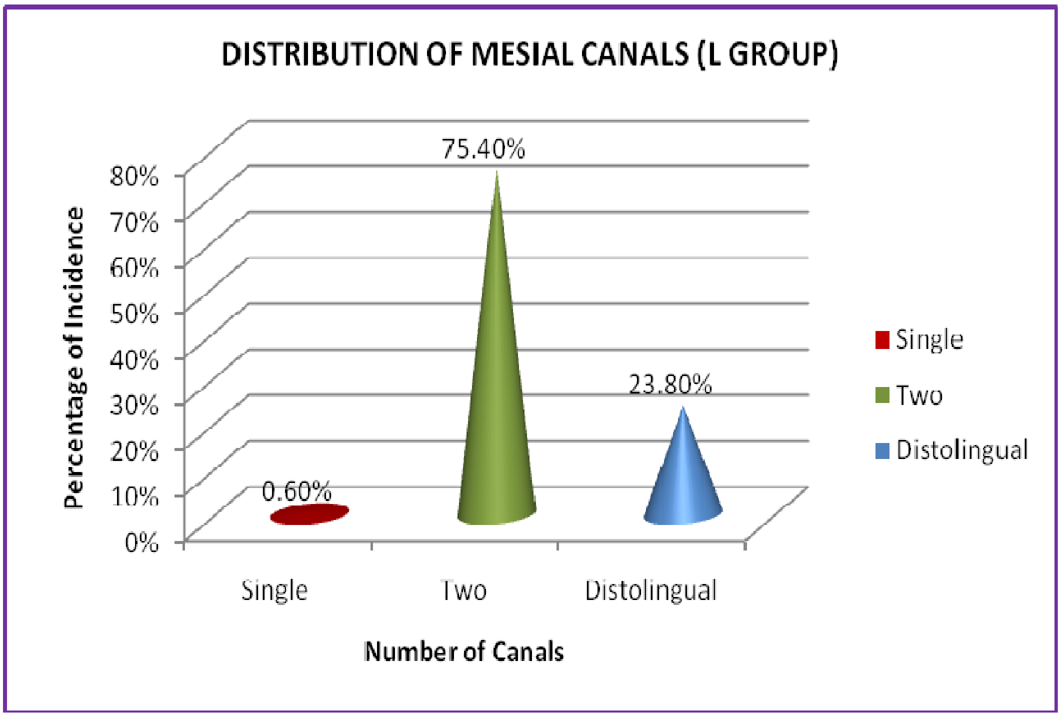
HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE III : DISTRIBUTION OF MESIAL CANALS

L GROUP

Total No. of samples (n=155)	Single Mesial	Two Mesial	Three Mesial
155	1	117	37
Percentage of incidence	0.60%	75.40%	23.80%

CHART III

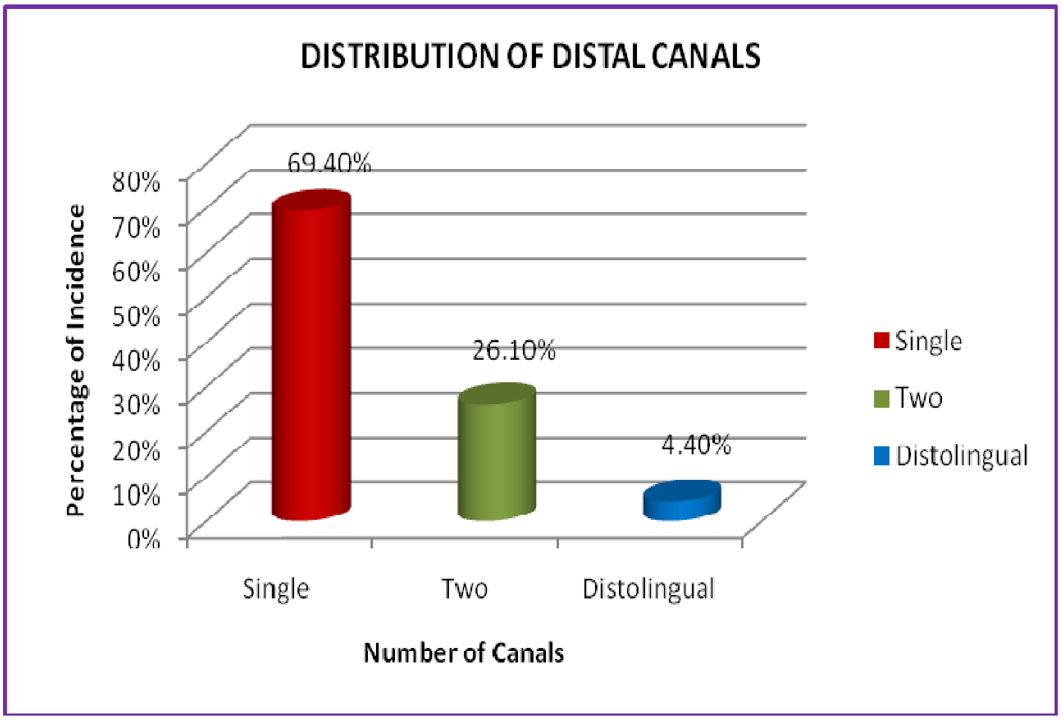


HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE IV : DISTRIBUTION OF DISTAL CANALS

Total No. of samples (n=314)	**Single Distal**	**Two distal**	**Distolingual (3 rooted)**
314	218	82	14
Percentage of incidence	69.40%	26.10%	4.40%

CHART IV



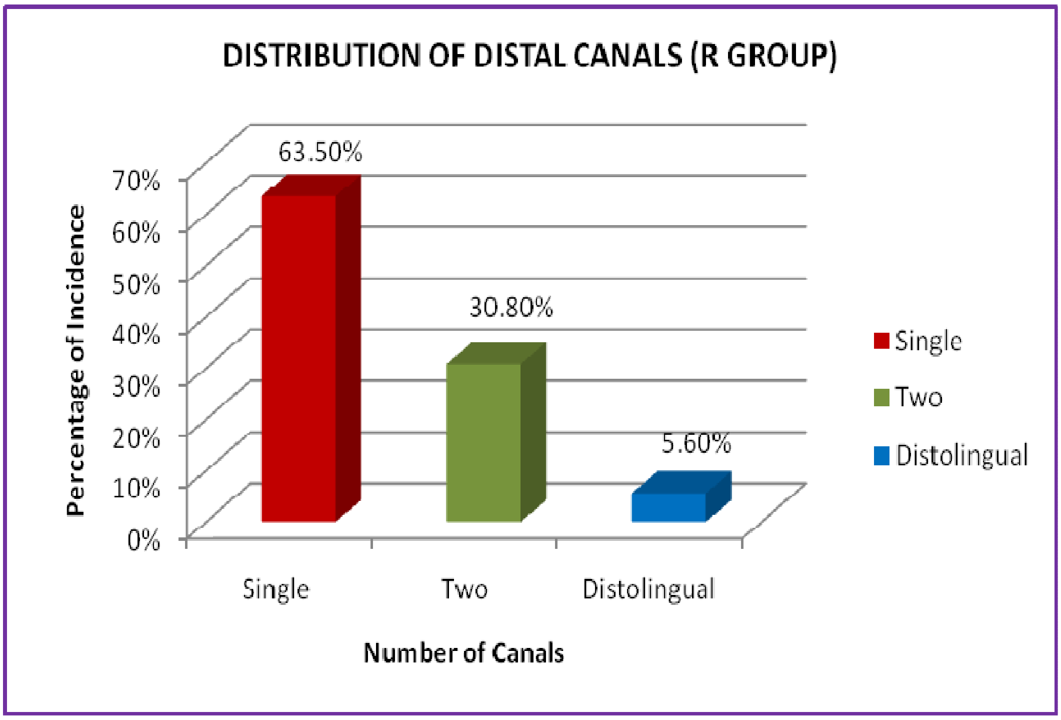
HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE V : DISTRIBUTION OF DISTAL CANALS

R GROUP

Total No. of samples (n=159)	Single Distal	Two distal	Distolingual (3 rooted)
159	101	49	9
Percentage of incidence	63.5%	30.8%	5.6%

CHART V



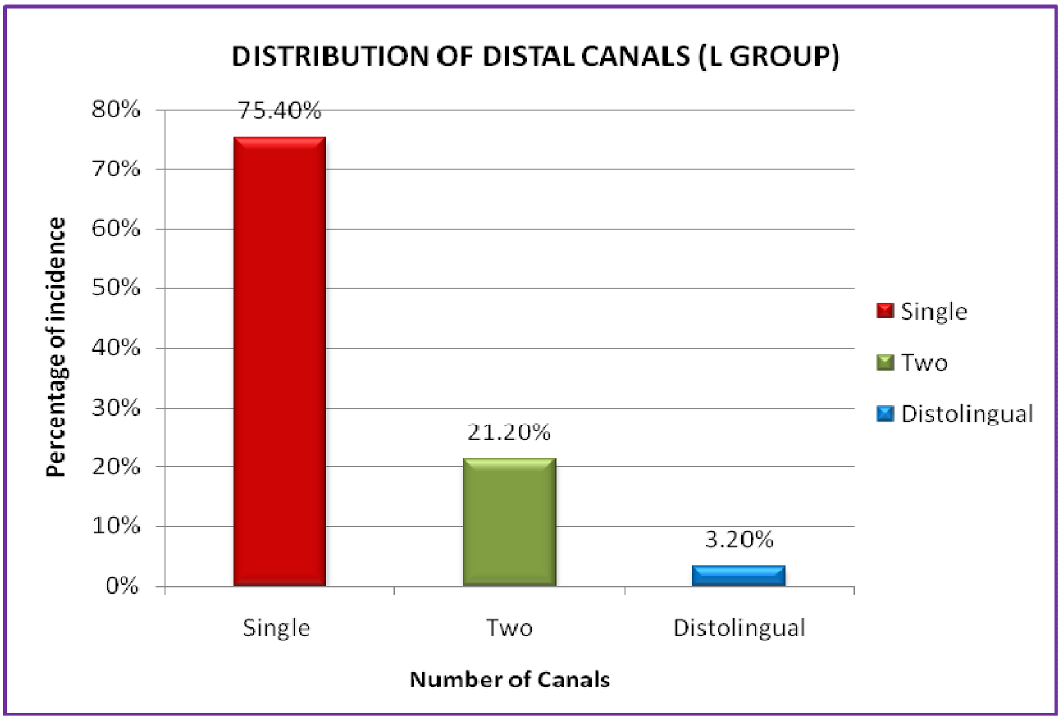
HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE VI : DISTRIBUTION OF DISTAL CANALS

L GROUP

Total No. of samples (n=155)	Single Distal	Two distal	Distolingual (3 rooted)
155	117	33	5
Percentage of incidence	75.4%	21.2%	3.2%

CHART VI

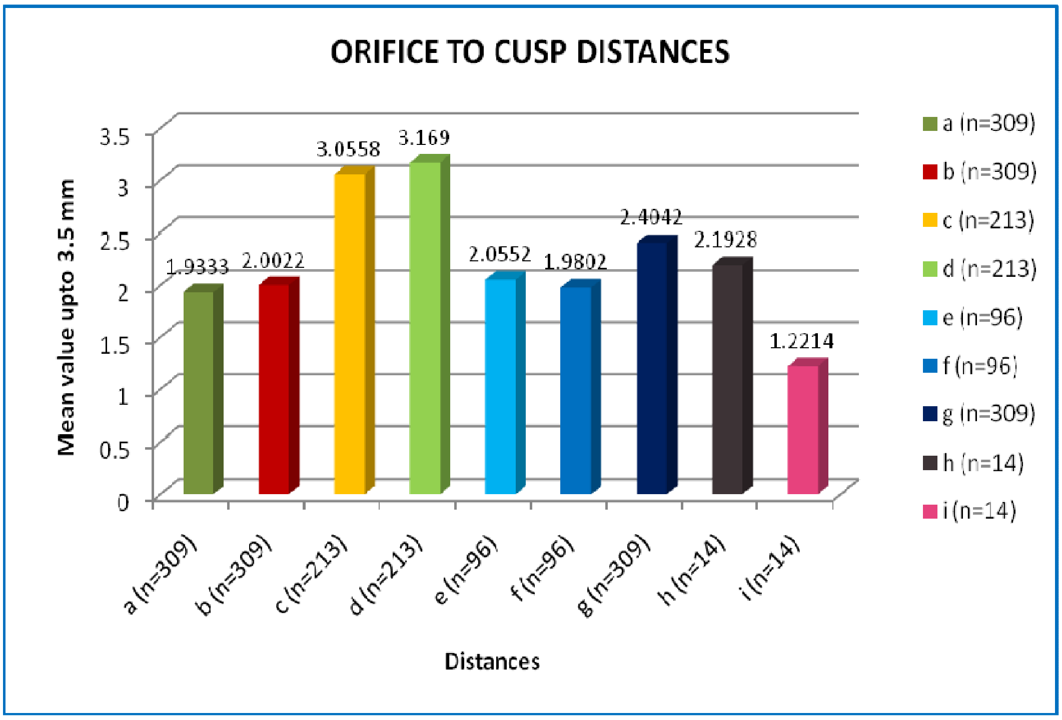


HUMAN PERMANENT MANDIBULAR FIRSTMOLAR

TABLE VII : ORIFICE TO CUSP DISTANCES

Distances (n=314)	Mean (mm)	Standard Deviation
a (n=309)	1.9333	0.46325
b (n=309)	2.0022	0.56470
c (n=213)	3.0558	0.68350
d (n=213)	3.169	0.53791
e (n=96)	2.0552	0.56993
f (n=96)	1.9802	0.52579
g (n=309)	2.4042	0.53832
h (n=14)	2.1928	0.47958
i (n=14)	1.2214	0.37013

CHART VII

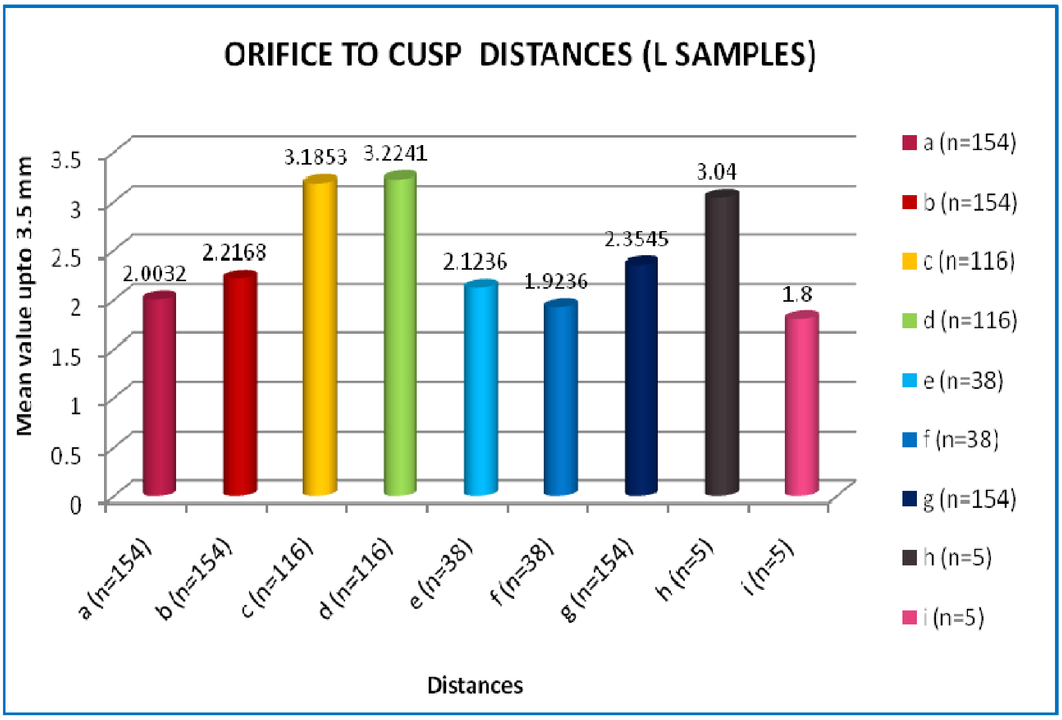


HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE VIII : ORIFICE TO CUSP DISTANCES (L SAMPLES)

Distances (n=155)	Mean(mm)	Standard Deviation
a (n=154)	2.0032	0.50483
b (n=154)	2.2168	0.66043
c (n=116)	3.1853	0.81691
d (n=116)	3.2241	0.57478
e (n=38)	2.1236	0.62350
f (n=38)	1.9236	0.53852
g (n=154)	2.3545	0.58654
h (n=5)	3.0400	0.45056
i (n=5)	1.8000	0.57879

CHART VIII

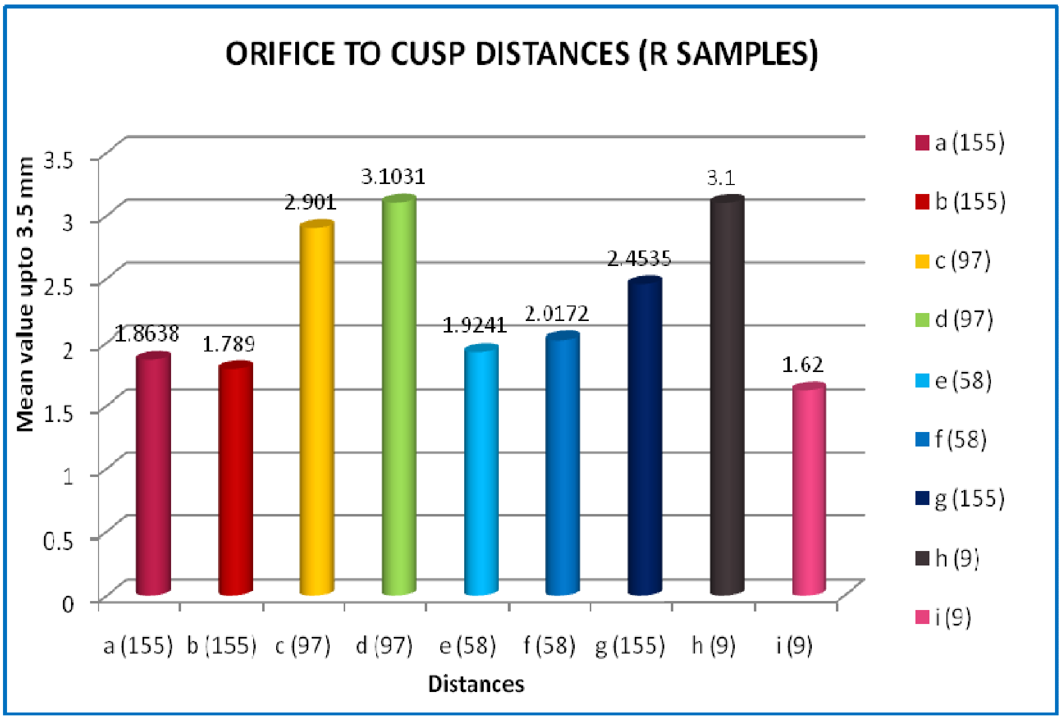


HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE IX : ORIFICE TO CUSP DISTANCES (R SAMPLES)

Distances (n=159)	Mean(mm)	Standard Deviation
a (n=155)	1.8638	0.41788
b (n=155)	1.7890	0.44986
c (n=97)	2.9010	0.47730
d (n=97)	3.1031	0.49021
e (n=58)	1.9241	0.53193
f (n=58)	2.0172	0.51728
g (n=155)	2.4535	0.48570
h (n=9)	3.1000	0.49497
i (n=9)	1.6200	0.16432

CHART IX

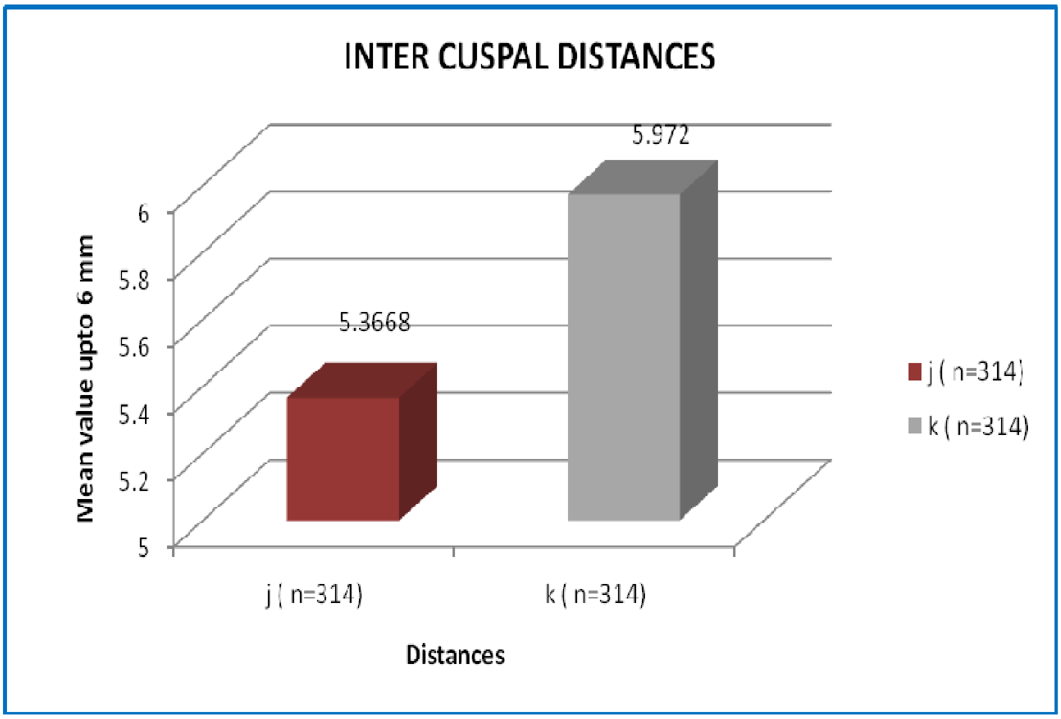


HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE X : INTER CUSPAL DISTANCES

Distances (n=314)	Mean(mm)	Standard Deviation
j (n=314)	5.3668	0.60249
k (n=314)	5.9720	0.70921

CHART X

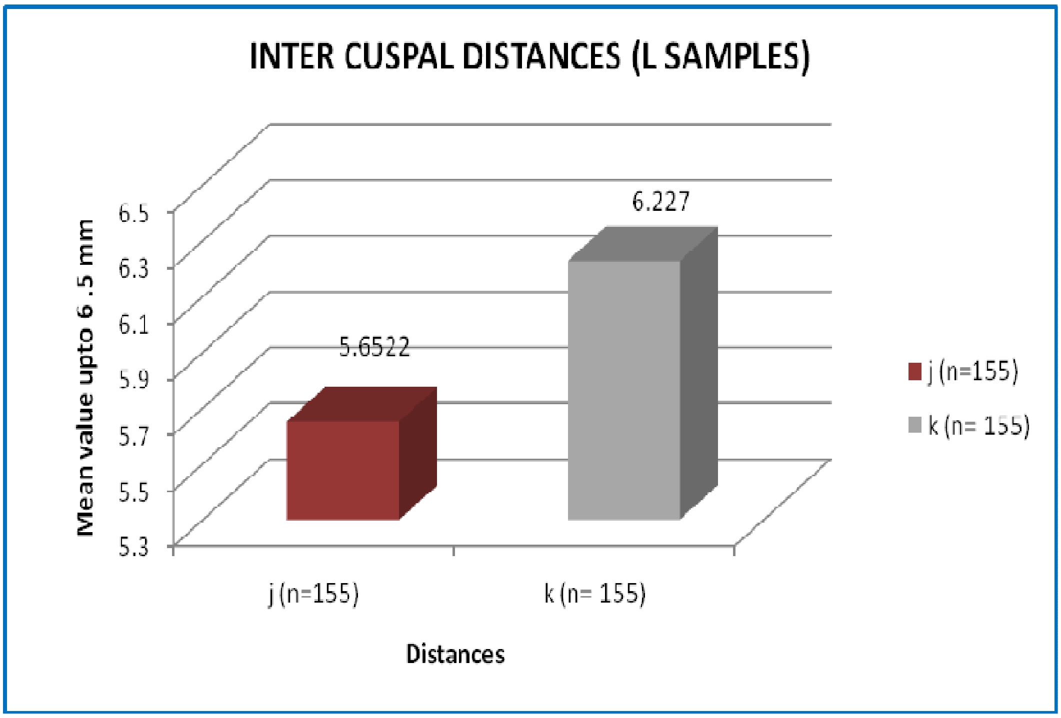


HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE XI : INTER CUSPAL DISTANCES (L SAMPLES)

Distances (n=155)	Mean(mm)	Standard Deviation
j (n=155)	5.6522	0.61706
k (n= 155)	6.2270	0.64391

CHART XI

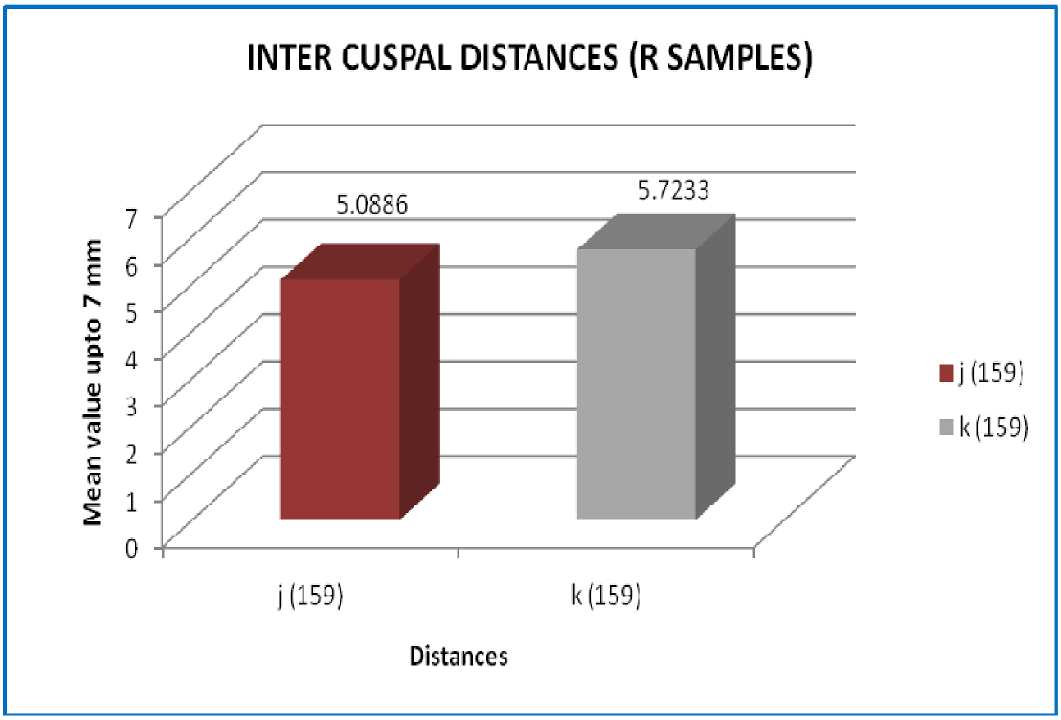


HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE XII : INTER CUSPAL DISTANCES (R SAMPLES)

Distances (n=159)	Mean(mm)	Standard Deviation
j (n=159)	5.0886	0.58794
k (n=159)	5.7233	0.76755

CHART XII

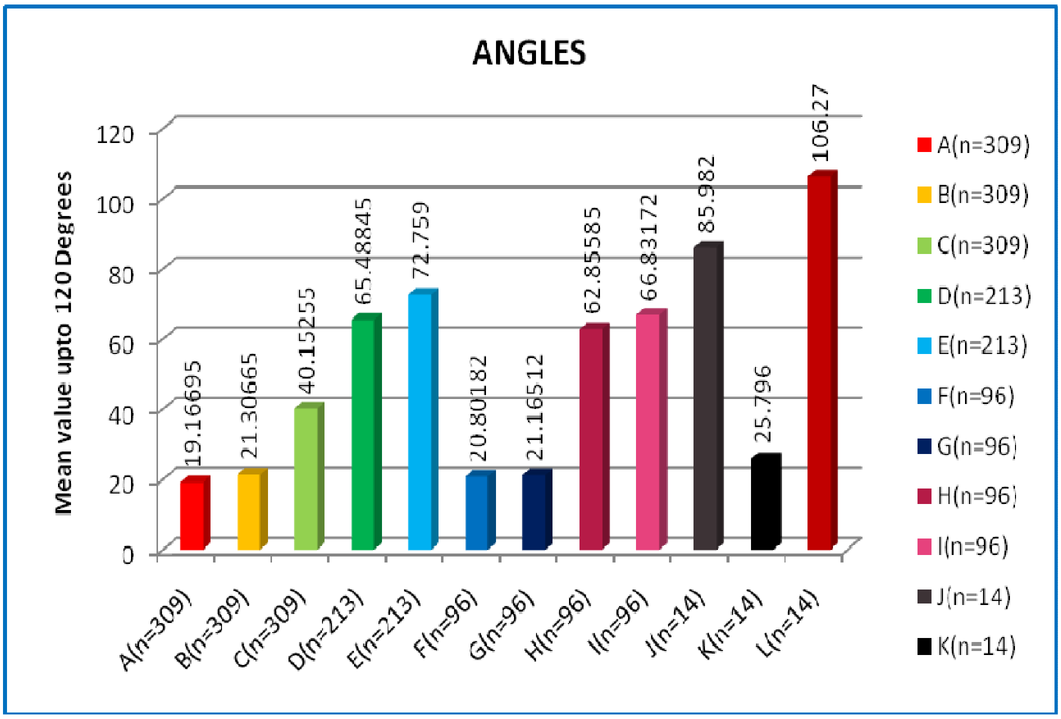


HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE XIII : ANGLES

Angles (n=309)	Mean	Standard Deviation
A(n=309)	19.16695	3.90052
B(n=309)	21.30665	4.03041
C(n=309)	40.15255	7.74288
D(n=213)	65.48845	7.29662
E(n=213)	72.75900	5.49794
F(n=96)	20.80182	5.43420
G(n=96)	21.16512	5.75894
H(n=96)	62.85585	8.48274
I(n=96)	66.83172	8.56960
J(n=14)	85.98200	23.17793
K(n=14)	25.79600	6.49120
L(n=14)	106.27000	10.56657

CHART XIII

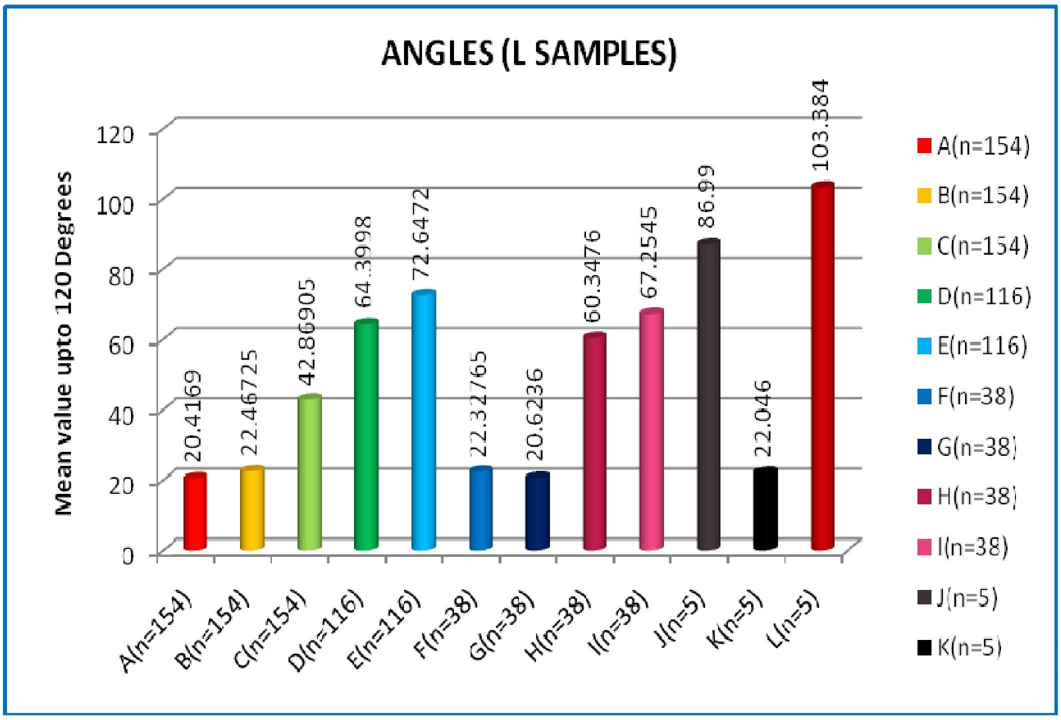


HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE XIV : ANGLES (L SAMPLES)

Angles (n=155)	Mean	Standard Deviation
A(n=154)	20.41690	3.92789
B(n=154)	22.46725	4.04127
C(n=154)	42.86905	7.56661
D(n=116)	64.39980	7.36914
E(n=116)	72.64720	4.32669
F(n=38)	22.32765	4.99579
G(n=38)	20.62360	5.21836
H(n=38)	60.34760	7.35348
I(n=38)	67.25450	10.97596
J(n=5)	86.99000	19.90617
K(n=5)	22.04600	5.52004
L(n=5)	103.38400	14.70252

CHART XIV

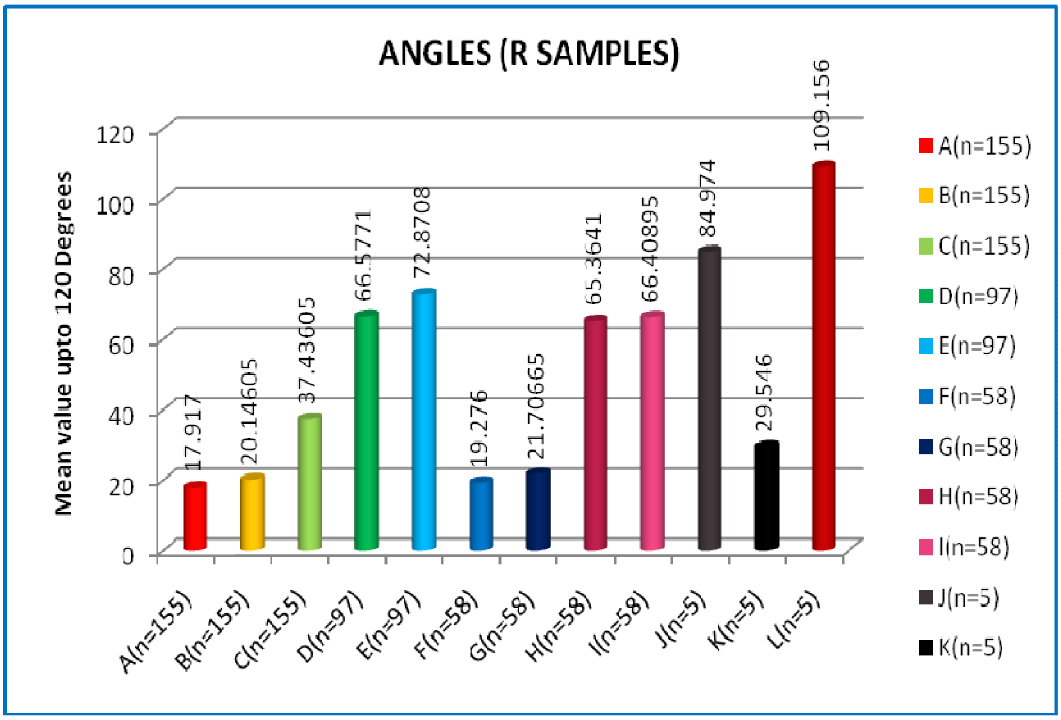


HUMAN PERMANENT MANDIBULAR FIRST MOLAR

TABLE XV : ANGLES (R SAMPLES)

Angles (n=159)	Mean	Standard Deviation
A(n=155)	17.91700	3.87313
B(n=155)	20.14605	4.01966
C(n=155)	37.43605	7.91413
D(n=97)	66.57710	7.20895
E(n=97)	72.87080	6.63238
F(n=58)	19.27600	5.70318
G(n=58)	21.70665	6.08714
H(n=58)	65.36410	9.14732
I(n=58)	66.40895	6.52863
J(n=5)	84.97400	25.24482
K(n=5)	29.54600	6.97253
L(n=5)	109.15600	7.32056

CHART XV



DISTAL ORIFICE DISTRIBUTION

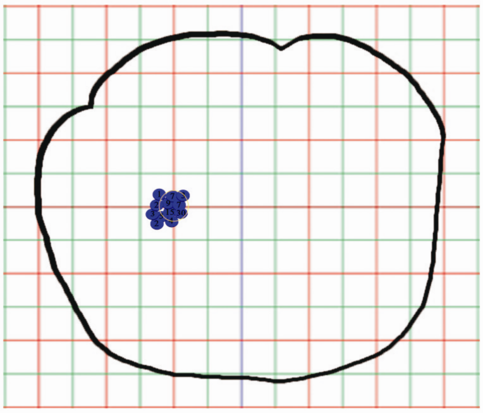


Fig 33 : Left single distal orifice

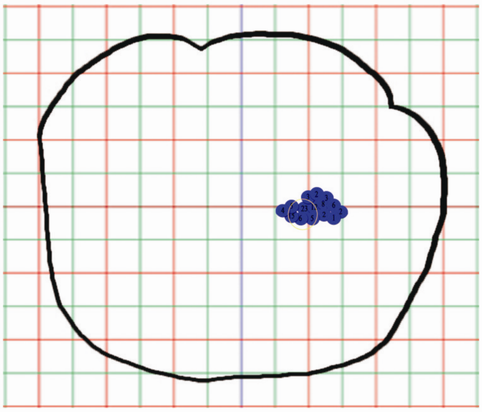


Fig 34 : Right single distal orifice

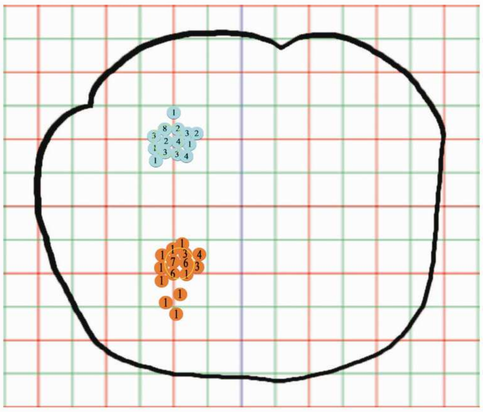


Fig 35 : Left two distal orifice

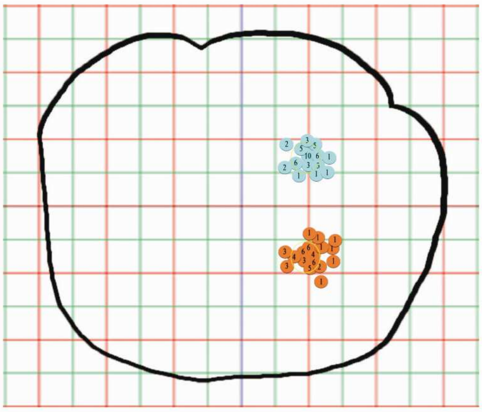


Fig 36 : Right two distal orifice

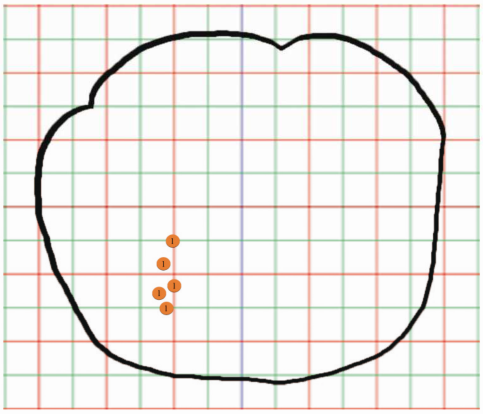


Fig 37 : Left distolingual orifice

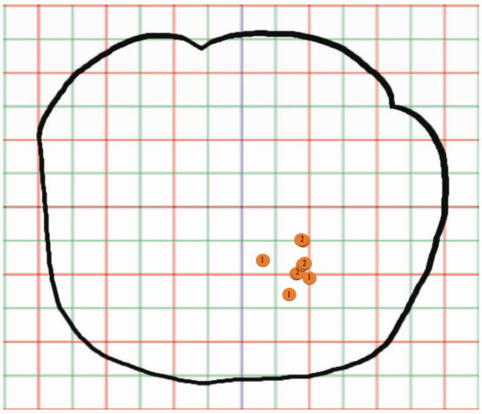


Fig 38 : Right distolingual orifice

MESIAL ORIFICE DISTRIBUTION

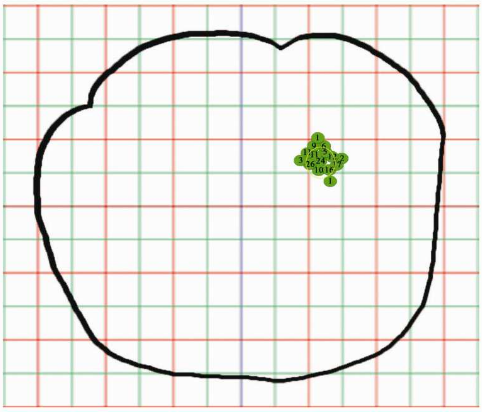


Fig 39 : Left mesiobuccal orifice

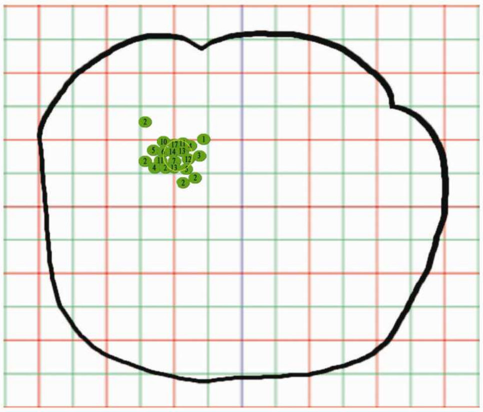


Fig 40 : Right mesiobuccal orifice

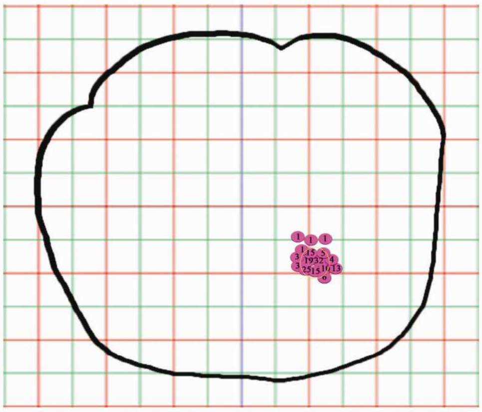


Fig 41 : Left mesiolingual orifice

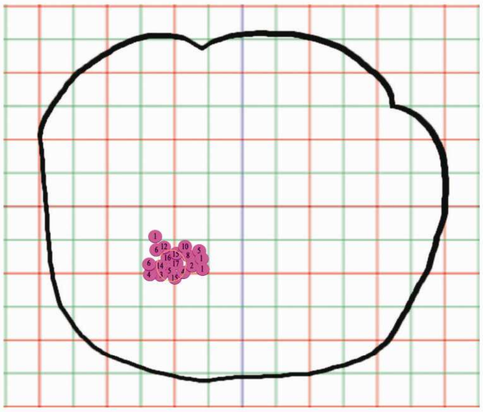


Fig 42 : Right mesiolingual orifice

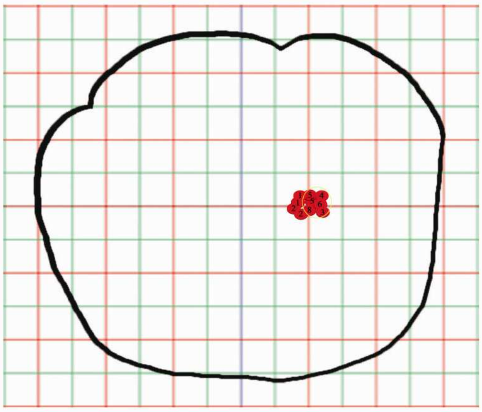


Fig 43 : Left middle mesial orifice

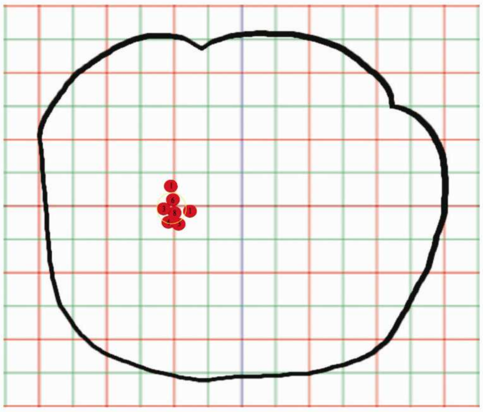


Fig 44 : Right middle mesial orifice

DISCUSSION

One of the common cause of failures during endodontic therapy is the inability to recognize and adequately obturate all the canals of the root canal system. (**Ingle.J in 1976**[38]). Achieving a hermetic seal is very important for success of root canal therapy in the long term. In a clinical situation all of the canals are not always found and the canals which are identified are not adequately obturated. Success of endodontic therapy depends not only on the technical abilities of the clinician, but possibly also on other factors such as the body's healing ability and potential, resistance to infection, the status of the immune system in that individual, the condition of the periapical tissues, the surrounding periodontium and the presence or absence of systemic disease. Other factors like age, sex, race, and tooth distribution might also possibly be contributory in certain cases for failure of endodontic therapy.

Apical percolation is one of the primary causes of failure of endodontic therapy leading to poor treatment outcomes and could possibly be due to the presence of microbial organisms present in the canal due to insufficient biomechanical preparation, inadequate canal obturation, seal and presence of untreated missed canals. Missed root or canals remain as a persistent source of infection and have been reported as a primary reason for retreatment with a incidence of as high as 42% **(Hoen & Pink in 2002**[34]**)**. It is therefore imperative for the clinician and operator to be pre-operatively aware of the complexities of the root canal spaces being treated. It is also extremely important that the operator uses all available technology and techniques at his disposal to pre-operatively assess, locate accurately, prepare the canals adequately and treat the entire root canal system. Even under the most challenging circumstances it is comforting to note that the current methods of root canal therapy results in exceptionally high rate of success in spite of the variations, difficulties and limitations encountered during endodontic therapy. **(Vertucci F.J. in 2005[80])**.

The permanent mandibular first molar is one of the first to erupt in the oral cavity at the age of six and is one which is most frequently treated endodontically. The human permanent mandibular first molar generally has two roots. Other variations in ethnic populations have been reported with varying incidence of which the three rooted mandibular first molar is the more common variation though there have been reports of four roots which is relatively rare. This tooth has generated a lot of interest in research and clinical investigations. They were generally thought to have three canals until it was first reported by **Vertucci and Williams[78] and Barker et al in 1974[4]** for the variations in the mesial root and its endodontic significance. Since then many authors have investigated the permanent mandibular first molar and published numerous articles on the type of variations in the roots, the root canal system and their clinical implications. The presence of a third canal in the mesiobuccal root, presence of a isthumus in between the canals of the mesial root is the commonest variation. Additional canals in the distal root, presence of a distolingual root and canal, presence of a isthumus between the two distal canals, and radix paramolaris have also been reported though comparatively less common. Teeth with five, six and seven canals have also been reported. C-shaped configuration of the canals, two canals and single canal have also been reported. A single canal though rare in the mandibular first molar, when present is usually located rather easily in the centre of the access preparation. A review of literature shows the occurrence of single canal mostly in mandibular second molar and very rarely in permanent mandibular first molar. **(Wiene et al in 1988[84])**. Variations of root morphology in the permanent mandibular first molars have been reported by various authors **(Ballulaya SV et al in 2013[3]).**

The middle mesial canal has been reported in different populations and has been studied widely. The middle mesial canal in the mandibular first molar was studied by **Mortman et al in 2003[51]** and they observed that the incidence of the isthmus in the mesial root is in about 54% to 89% of cases, most frequently between 4mm and 6mm from the apical foramen. They also note that the third mesial canal is not an extra canal but rather the sequlae of instrumentation of the isthmus between the mesiobuccal and mesiolingual canals. The presence of middle mesial canal in the mesial root of mandibular permanent first molars has been reported at varying rates of incidence of 1 to 17.2% (**Baugh et al in 2004[8]**). The middle mesial canal has also been reported to be more easily located in younger individuals. **Pomeranz et al in 1981[58]** classified middle mesial canal into three separate morphological entities namely :

- a *fin* when the instrument could pass freely between the mesiobuccal or mesiolingual canal and the middle mesial canal.
- *confluent* when the prepared canal originated as a separate orifice and joined the mesiobuccal or mesiolingual canal apically.
- *independent* when the prepared canal originated as a separate orifice and terminated via a independent foramen apically.

Fabra-Campos in 1985[23] suggested various methods and useful techniques to locate the middle mesial canals in the mesial root of the first permanent mandibular first molar.

- In vital teeth the presence of a bleeding spot can indicate the presence of a middle mesial canal
- Removal of the dentinal protuberance which separates the entrance to the mesiobuccal and mesiolingual canals with either ultrasonic tips or round bur
- The groove connecting the mesiobuccal and mesiolingual canal is explored with a explorer to search for any possible intermediate depression.
- Negotiation of the third canal using a thin file (# 06 ,08 or 10) in a slow and alternating 45 degrees rotation with care not to twist the file.
- After location, the canal orifice is subsequently enlarged with caution.

Most often the middle mesial canal will join the mesiobuccal or mesiolingual canal at the apical or the middle third of the root to exit via a single foramen apically. The middle mesial canal once identified should be prepared with caution as there is a risk of perforation due to the smaller size when compared with the mesio-buccal and mesio-lingual canals. The thinner size of the preparation also makes obturation of the root canal much more challenging as instruments cannot be inserted to the right level during lateral condensation techniques. **(Fabro-Campos in 1985**[23]) The chance of the middle mesial canal being identified successfully is lesser with progression of age. Age of the patient on being a vital predictor of detection of fewer canals has been previously reported. This is more likely due to the calcifications and morphologic changes that occur with age. The original shape of the canals are not affected but they get narrower with advancing age. This narrowing effect might cause difficulties in the detection, bio-mechanical preparation and subsequent obturation of these canal systems**.** The middle mesial orifices located not always have a fully negotiable canal. In the present study non-negotiatable and blocked canals were excluded and only canals which were negotiable to the apex or just short of apex were included.

The clinician should use multiple approaches and techniques as appropriate in the situation to identify extra canals and orifices routinely. A careful clinical examination procedure with a careful analysis of the pulpal floor morphology, exploring the pulp chamber floor with a sharp explorer, multiple preoperative radiographs from different angulations, their subsequent analysis using digital analysis software designed for the purpose, staining the pulp chamber floor, visualization of bleeding points and with use of magnification and analysis, troughing of the grooves with ultrasonic tips, use of appropriate computerised tomography techniques, the canals can be precisely detected. negotiated and successfully treated.

Taurodontism has been reported by various researchers though the frequency of incidence is very low. Taurodontism can be defined as a change in tooth shape caused by the failure of Hertwig's epithelial sheath diaphragm to invaginate at the proper horizontal level. An enlarged pulp chamber, apical displacement of the pulpal floor, and no constriction at the level of the cementoenamel junction are the characteristic features. It appears most frequently as an isolated anomaly, but its association with several syndromes and abnormalities has also been reported. Some reports suggest that taurodontism may be genetically transmitted and could be associated with an increased number of X chromosomes. However other researchers have found no simple genetic association but have noticed a trend for X chromosomal aneuploidy amongst patients with more severe forms of the trait. Autosomal transmission of the trait has also been observed. These chromosomal abnormalities may disrupt the development of the tooth's form however a specific genetic abnormality cannot be attributed to taurodontism. Taurodontism occurs in down's and Klienfelter's syndrome and is associated with these genetic abnormalities but today the view is that it is a anatomic variance that could also possibly occur in a normal population.

Clinically, a taurodont tooth appears as a normal tooth. In fact, because the body and roots of a taurodont tooth lie below the alveolar margin, its distinguishing features cannot be recognized clinically. Therefore, the diagnosis of taurodontism is usually a subjective determination made from diagnostic radiographs. In performing root canal therapy on these teeth, one should appreciate the complexity of the root canal system and appropriate adjustments to the endodontic procedure and protocols should be made. Normal pulpal foor morphology will not be present and careful exploration of the grooves between all orifices, particularly with magnification, ultrasonic irrigation, and a modified technique for obturation is recommended. Use of modern tomographic techniques of volumetric assessment and 3D analysis would be very appropriate. In the present study no taurodont tooth was encountered.

"C" shaped configuration, which is an important anatomic variation, presents a thin fin connecting the root canals. Cooke and Cox in 1979 first used the term "C-shaped canal" in 1979. Instead of having several discrete orifices, the pulp chamber of the C-shaped canal is a single ribbon-shaped orifice with a 180° arc (or more), which, in mandibular molars, starts at the mesiolingual line angle and sweeps around the buccal to the end at the distal aspect of the pulp chamber. Below the orifice level, the root structure can harbor a wide range of anatomic variations. These can be classified into two basic groups:

(1) Those with a single, ribbon-like, C-shaped canal from orifice to apex and

(2) Those with three or more distinct canals below the C-shaped orifice.

Fortunately, C-shaped canals with a single confluent canal is the exception rather than the rule. They reported cases where the root canals of the teeth looked like the capital letter “C” when the pulp chamber had been opened. The canals are connected by a continuous slit on the pulp chamber floor. This C-shaped canal is an anatomical variation of a root fusion. This results from the failure of Hertwig’s epithelial sheath to develop or fuse in the furcation area in the developing stage of the teeth. Failure on the buccal side will result in a lingual groove, and the opposite cases would be possible. Failure on both sides will result in the formation of a conical or prism-shaped root. C-shaped canal is most frequently found in the mandibular second molar, although it could be found in the mandibular first premolar, the mandibular first molar , the maxillary first molar, and the maxillary second molar. While a 2.7-7.6% prevalence was reported in a study of the Caucasian population, the prevalence was higher in middle Asia up to 10.6% in Saudi Arabians and 19.14% in lebanese. In northeast Asia, the prevalence was 31.5% in Chinese and 32.7% in Koreans. The C-shaped canal provides a challenge with respect to debridement and canal obturation, especially because it is unclear whether the C-shaped canal orifice found on the floor of the pulp chamber actually continues to the apical third of the root. Modern non-invasive analysis by tomography could lend a valuable insight in these cases. C-shaped canal must be suspected when the roots are fused or very close to each other. A number of factors contribute to variations observed in these studies as the root canal anatomy is often extremely complex and highly variable. These variations may be attributed to ethnic background, age, gender of the population, whether the study is in-vivo or in-vitro, technology used for the conduct of the study, sample size analysed etc. The location and treatment of these canals have improved with the introduction of magnification and tomographic techniques of non-invasive 3D analysis of the root structure. In the present study the incidence of C shaped canals was 0.0% **.**

Transverse communications exist between canals and are called an an isthmus. It is a narrow ribbon shaped communication that exists between two root canals that contains pulp or pulp derived tissues. It can also function as a reservoir for debris and microbes. Presence of more than a single canal is a potential candidate an isthmus and must always be suspected. The mesial roots of mandibular first molars, which presented two canals close to 89%, and the chance of finding an isthmus is quite high. The actual formation of the isthmus from embryonic origin is through the epithelial root sheath. In teeth with single roots, the inner cells of the root sheath next to the dental pulp differentiate into odontoblasts and start secreting dentin matrix. As this matrix is laid down and begins mineralizing, the epithelial root sheath cells secrete a thin layer of cementum on this newly formed dentin structure. The cells then continue to form dentin and cementum while breaks occur within the root sheath epithelium. Degeneration of these root sheath epithelial cells allows mesenchymal cells or ectomesenchymal cells to migrate into these areas and differentiate to form cementoid to fill these gaps. Cementum production continues as the tooth erupts into the oral cavity until root formation is complete. Occasionally, defects in the root sheath can be found. If the epithelial cell is defective, an odontoblast does not differentiate. Thus, dentin formation does not occur. Without dentin formation, cementum is not deposited in this area which then leads to lateral and accessory canals, which is commonly observed in the apical third of the root. In multi-rooted teeth and roots with multiple canals, however, another mechanism takes place. The mechanism of root formation is similar to a single root trunk except in the furcation area where the tooth divides. Tongue like projections of the epithelial root sheath develop and proliferate until contact is made with other projections allowing fusion take place. These epithelial projections then continue to proliferate and divide. The original large opening forms two, three, or four openings, which eventually become the orifice. As these multirooted areas continue to grow, defects can occur during normal root formation similar to a normal single root. Defects occur in multirooted teeth with a high incidence and in such a situation the tongue-like projections of the epithelial root sheath do not completely fuse with one another. When this occurs, lateral or accessory canals in the furcation area can form. An isthmus is formed when an individual root projection is unable to close itself off. Therefore, the approximation of the root projections can fuse completely and form one root with one root canal system as in the distobuccal root of maxillary molars. Alternatively, partial fusion results in the formation of two root canals with an isthmus formed in between, such as the mesial root of the mandibular first molar. No fusion leads to a large ribbon-shaped canal that also forms an isthmus throughout the entire root, which is a common finding in the distal root of the mandibular first molars. In the past, the canal isthmus was often overlooked, and it was also difficult to prepare if located. Now, with newer irrigant combinations and sequencing, the use of magnification, image analysis and microsurgical equipment, clinicians can view the resected root surface better, identify the isthmus, and prepare it with an ultrasonic tip. The recognition and management of the canal isthmus is one factor that would definitely improve rate of success of surgical endodontic procedures in posterior teeth. The incidence of isthmus in mandibular first molars has been reported both in the mesial and the distal root. **Hsu and Kim in 1997**[36] in their detailed study of the isthmuses in the mesial root of mandibular first permanent molars classified them into five different types :Type I - two separate canals, Type II - two separate canals joined by an isthmus, Type III - three canals joined by an isthmus, Type IV - two elongated canals that join in the centre and Type V - a single, very broad and elongated canal. The debris, remnants and organic substrates present in these areas support and provide conditions ideal for growth of microorganisms. The cleaning and shaping procedures should include these isthmus areas and accessory canals. Failure to seal the accessory canal might eventually lead to failure of surgical and non surgical endodontic therapy.

The improved access preparation definitely increases the chances of the detection of additional canals. Access cavity preparation is very vital to successful endodontic therapy as the preliminary step permits localization, cleaning and shaping, disinfection and three dimensional obturation of the root canal space. The success of the therapy depends on precise, proper execution of this step. **(Georghita et al in 2009**[27]) This should include removal of the remaining roof of the pulp chamber and allow direct visualization of the pulp chamber floor, which aids location of orifices via proper dentinal mapping. Access preparation should also facilitate instrumentation of the canals by providing a straight line access with the instrument not touching the canal walls. The access cavity should always have intact walls to help the irrigant stay within the confines of the tooth structure which promotes irrigant exchange and replacement. We encountered a second distal orifice in 26.10% of samples and a distolingual orifice in 4.40% of the samples. Though the prevalence of these type of variations is relatively less common in the mandibular first permanent molar teeth, the clinician should be aware of these less frequent variations and lookout for them by proper probing and visualizing the pulp chamber floor as knowledge of these pre-operative predictors leads to identification of these aberrant and morphologic variations of anatomy and paves way for successful endodontic therapy.

Various diagnostic techniques and methodologies have been developed which help the clinician identify extra canals. Radiography was first used to identify the location and number of canals. Radiographs from different angles helped the clinician to make a judgement of the presence of extra canals. Introduction of digital radiography, made ease of archiving, transmission, and long distance consultations possible. They also reduced the radiation exposure and digital documentation of the patient records was made possible. Software manipulation of these images helped locate missed canals, calculate working lengths, and observe the apices of root canals for infection and proper termination of the restoration. Detection and location of the orifices in the pulp chamber can be effectively achieved adopting various methodologies **(Karunakaran et al in 2012[43]**):

1) Proper exploration of the chamber floor with a sharp DG-16 probe.

2) Mapping the anatomical landmarks of the pulp chamber floor

3) Use of magnification techniques

4) Use of Staining techniques

5) Observing the bleeding points during access preparation

6) Troughing

7) Use of ultrasonics

8) Performing a bubble test using sodium hypochlorite.

9) Proper access preparation

10) Using modified access outlines

11)SLOB technique

12) Use of computerized tomography

13) Use of cone beam CT

14) Ensuring proper training of the operator

15) Operator persistence and scheduling adequate clinical time.

16) Familiarity and understanding the laws of the pulp chamber.

Though various diagnostic methods have been advocated the clinician can further improve the access cavity design by co-relating it with the location of the root canal orifices **(Vertucci F.J. 2005[80]).** In most cases it has been the accepted practice to make an access in an appropriate position in the clinical crown and look for orifices in the hope that they would be eventually found. There is little guidance for locating three orifices without danger of perforation, or excessive tooth loss. Further looking for orifices in teeth in which endodontic therapy has already been done or attempted or in angulated teeth, and broken drown teeth is very difficult as the normal anatomy is severely distorted. If specific landmarks can be identified and if they are quantifiable the process of orifice location can be made more systematic, rational and easier for the operator. Various laws of the pulpal chamber and pulp floor have been put forward by **krasner and Rankow in 2004[46].** They describe the centrality, concentricity, symmetry and the relationship of the cemento-enamel junction and orifices to the pulp chamber floor. They also put forward various laws on the pulp chamber floor which help location of these orifices with ease. Their study proved that consistent patterns of both the pulp chamber and the pulp chamber floor were present. These laws will help the clinician locate the orifices as they are based on sound principles. They also have identified the cemento-enamel junction as the most consistent landmark for location for the pulp chamber and directing access. They recommend that that the knowledge of these basic laws is more important for the clinician and that with this knowledge the use of supplementary tools and instruments like microscopes can be rationally used as valuable tools.

The various angular relationships between the orifices were computed for teeth with single distal orifices (69.40%) and were angle A(19.1), angle B(21.3), angle C(40.1), angle D(65.4) and angle E(72.7), for teeth with two distal orifices (26.10%) and were angle F(20.81), angle G(21.16), angle H(62.85) and angle I(66.83), for teeth with disto-lingual orifices (4.40%) and were angle J(85.98), angle K(25.79) and angle L(106.27) [Table:XIII Chart:XIII].This in-vitro study utilized advanced image analysis and manipulation techniques to obtain quantitative results without the need for location of the root orifices by separate evaluators, consensus scoring in borderline cases or statistical procedures for determining inter examiner reliability.

The use of magnification either as loupes or the surgical operating microscope has definitively increased the percentage of identification of additional canals and orifices. A number of researchers have reported a increased incidence of canal orifice location with the use of magnification. The benefits of using magnification devices for conventional endodontic treatment include the increased visualization of the treatment field, enhanced possibilities in locating canals, aid in the removal of separated instruments, diagnosis of root and tooth fractures, perforation repair, and case documentation. They are also used in endodontic surgery where the use of magnification improves the ability to locate, clean, and fill the root canal system, thus achieving a predictable outcome. It is unknown if and how the type of magnification device affects the treatment outcome, considering the high number of factors that may have a significant impact on the success of endodontic surgical procedure. The true difference in terms of treatment success rates between using or not using a magnification device in both conventional and surgical endodontic treatment, should be evaluated**.**

In some instances the most important factor in locating the extra canal orifice is not the magnification but the persistence of the operator**.** Conventional radiographs used for the management of endodontic problems yield limited information because of the two-dimensional nature of images produced, geometric distortion and anatomical noise. These factors often act in combination. Thus there are limitations in the use of periapical radiographs and other methodologies especially three-dimensional imaging techniques have been suggested as adjuncts to conventional radiographs. These include tuned aperture computed tomography, magnetic resonance imaging, ultrasound, computed tomography and cone beam computed tomography (CBCT). Of these techniques, CBCT appears to be an effective and safe way to overcome some of the problems associated with conventional radiographs.. Cone beam computed tomography (CBCT) has been specifically designed to produce undistorted three-dimensional information of the maxillofacial skeleton, including the teeth and their surrounding tissues with a significantly lower effective radiation dose compared with conventional computed tomography (CT). Periapical disease may be detected sooner using CBCT compared with periapical views and the true size, extent, nature and position of periapical and resorptive lesions can be assessed. Root fractures, root canal anatomy and the nature of the alveolar bone topography around teeth may be assessed. All radiographic examinations must be justified on an individual needs basis whereby the benefits to the patient of each exposure must outweigh the risks. In no case may the exposure of patients to X-rays be considered "routine", and certainly CBCT examinations should not be done without initially obtaining a thorough medical history and clinical examination. CBCT should be considered an adjunct to two-dimensional imaging in dentistry. Limited field of view CBCT systems can provide images of several teeth from approximately the same radiation dose as two periapical radiographs, and they may provide a dose savings over multiple traditional images in complex cases. In this study the occlusal plane was divided into four quadrants and the position of the orifices noted and related to the cusp tips. In a clinical situation the ideal occlusal morphology may not be always encountered. Teeth with loss of cusp or the references in the occlusal surface may present difficulties in the location of the orifices.

The success of endodontic therapy is based on a number of criteria, particularly the conservation of tooth structure. This principle requires a systematic approach to pulp chamber access. The location of the orifices can be particularly difficult in teeth which have been restored extensively, tilted or with calcifications. If the clinician is aware of all the possible anatomic variations in the mandibular first molars, such iatrogenic errors can be reduced. Further the pre-operative predictors of the number of root canal orifices provides a vital information to the clinician. The orifice location could be co-related to the occlusal anatomy, and a number of guidelines for improving access design could be achieved. Operator experience has also shown to be very valuable and a positive factor in identifying and obturating extra canals. The use of magnification and tomographic techniques have also contributed to the identification of extra canals and orifices and their effective obtuation. Given the fairly consistent location of these orifices, understanding their relationship to each other and to the occlusal dimension helps the operator in location of the orifices, reduces clinical time for both the operator and the patient, and makes the procedure more acceptable.

The occlusal surface of the mandibular permanent first molar presents with consistent landmarks. These landmarks if analysed and co-related to the location of the pulpal floor and the orifices would greatly aid in access design. In this study the relationship of the cusp tips with that of the orifices as linear distances have been evaluated. This helps the clinician to precisely plan his access preparation, locate the canals easily and reduces clinical time with minimal loss of tooth structure.

In this current study on the mandibular first molar in a south indian population the following linear distances have been observed. The mesio-buccal cusp tip to mesio-buccal orifice, distance a (1.93mm), mesio-lingual cusp tip to mesiolingual orifice, distance b (2.0mm), disto-buccal cusp tip to distal orifice, distance c (3.05 mm), disto-lingual cusp tip to distal orifice, distance d (3.16

mm), and distal cusp tip to distal orifice, distance g (2.40 mm) were observed in the mandibular first molar with a conventional presentation of three orifices, disto-buccal cusp tip to distal one orifice (D1), distance e (2.05 mm), disto-lingual cusp tip to distal two orifice (D2), distance f (1.98 mm), for two distal orifice presentation, distal cusp tip to midpoint of distal-distolingual orifice, distance h (2.19 mm), disto-lingual cusp tip to disto-lingual orifice, distance i (1.22 mm),. [Table:VII Chart:VII].

The frequency of incidence of the disto-lingual root was upto14.4% and was associated with certain ethnic populations as observed in their review by (**Abella et al in 2012**[2]). The authors noted that variable results were reported related to side of occurrence of the disto-lingual root and there was a trend towards bilateral incidence. They also observe that the ideal technique to identify the presence of the disto-lingual root is a 25° mesial parallax periapical radiograph or cone-beam computed tomography (CBCT).

The instrumentation of the disto-lingual root when present requires a different access preparation with the shape of the access being modified to trapezoidal. Pre-operative assessment and confirmation of this variation helps us make suitable changes to the access preparation and subsequent instrumentation. The length of the disto-lingual roots in general is shorter than that of the disto-buccal root and have a greater angle of curvature and a smaller radius of curvature in a bucco-lingual orientation. Clinicians should be aware of the variable furcation levels during coronal pre-flaring or post-space preparation to avoid furcal/strip perforations and a weakening of the disto-lingual roots. Small, flexible instruments, should be used to access these canals given the curvature of the disto-lingual root that is usually present buccally in the apical third.(**De Pablo et al in 2010[19]).** In the samples with the distolingual root in current study co-relating the cusp tips with that of the disto lingual orifice location linearly in the same plane the following linear distances were observed: distal cusp tip to distal-distolingual midpoint , distance h (2.19 mm), and distolingual cusp tip to distolingual orifice, distance i (1.22 mm). [Table:VII Chart:VII]

Complex root canal system presentation requires specialized training for the clinician and may most often be beyond the management ability of the operator with average skills. Appropriate access modifications have to be done to locate extra roots and canal orifices. For this the clinician should be able to anticipate or predict fairly the occurrence of the variations. Once having done that he should make a planned access preparation co-relating the occlusal surface morphology with that of the pulpal floor. This would enable the clinician to locate the orifices easily and prepare them with minimal loss of tooth structure as well as reduce the clinical time.

SUMMARY

Four hundred and two mandibular first molar teeth were collected, cleaned and stored in 1% thymol solution at 30^0 C. Three hundred and fourteen teeth were selected for the study and were divided into two groups .Group L (left mandibular first permanent molars) and GROUP R (Right mandibular first permanent molars).

The selected samples were processed, polished, smoothened, coded and stored, Both L and R groups were stored seperately. Imaging was done using a specially constructed customized jig and the images stored. All the samples were subsequently sectioned at the level of the cemento-enamel junction, marked and stored.

The pulp chambers were cleansed, debrided and orifices located. They were observed under a magnification of 12.8x and the orifice data with regard to number of canals and variations recorded after verification. Subsequently imaging was done using the jig and the images stored for analysis.

They were analysed using special image analysis software. The centres of the orifices were marked using software tools and the various datas of various angles representing the relationship of orifices to each other, inter-canal distances, various cusp to orifice distances, intercuspal diostances and distribution of mesial and distal orifices recorded.

The results were tabulated and statistically analysed.

CONCLUSION

On completion of this in-vitro study on the evaluation of the inter-relationship of the root canal orifices and their correlation to the occlusal morphology of human mandibular permanent first molar teeth the following conclusions were made:

1. The various angular relationships between the orifices were computed for teeth with single distal orifices (69.40%) and were angle A(19.1), angle B(21.3), angle C(40.1), angle D(65.4) and angle E(72.7). [Table:XIII Chart:XIII]

2. The various angular relationships between the orifices were computed for teeth with two distal orifices (26.10%) and were angle F(20.81), angle G(21.16), angle H(62.85) and angle I(66.83). [Table:XIII Chart:XIII]

3. The various angular relationships between the orifices were computed for teeth with disto-lingual orifices (4.40%) and were angle J(85.98), angle K(25.79) and angle L(106.27). [Table:XIII Chart:XIII]

4. The various linear relationships between the orifices were computed and their means were: mesio-buccal cusp tip to mesio-buccal orifice, distance a (1.93mm), mesio-lingual cusp tip to mesiolingual orifice, distance b (2.0mm), disto-buccal cusp tip to distal orifice, distance c (3.05 mm), disto-lingual cusp tip to distal orifice, distance d (3.16 mm), and distal cusp tip to distal orifice, distance g (2.40 mm) in the mandibular first molar with a conventional presentation of three orifices, disto-buccal cusp tip to distal one orifice (D1), distance e (2.05 mm), disto-lingual cusp tip to distal two orifice (D2), distance f (1.98 mm), for two distal orifice presentation, distal cusp tip

to midpoint of distal-distolingual orifice, distance h (2.19 mm), disto-lingual cusp tip to disto-lingual orifice, distance i (1.22 mm),. [Table:VII Chart:VII].

5. The mesiobuccal orifice was located closest to the mesiobuccal cusp tip at 1.93 mm distally, towards the mesio-distal midline, the mesiolingual orifice was located closest to the lingual cusp tip at 2.00 mm distally, towards the mesio-distal midline, the distal orifice was located from the disto-buccal cusp tip at 3.00 mm towards the mesio-distal midline and distolingual cusp tip at 3.16 mm onwards the mesio-distal midline with a slight distal tilt and the cusp tips could be used as a constant reference point for location of the orifices and designing access preparation. [Table:VII Chart:VII]

6. Based on the results of the analysis, the orifices were fairly consistently located in relation to each other, irrespective of the size or the position of the tooth. The angles and distances were fairly symmetrical for the L and R groups which confirms the concept of quantifiable pulpal floor morphology.

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